# DISTRIBUTION OF HUNTER GROUPS AND ENVIRONMENTAL EFFECTS ON MOOSE HARVEST IN INTERIOR ALASKA

By

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ABSTRACT

Moose (*Alces alces*) is one of the most valuable wild game resources in Interior Alaska. In recent years, residents of rural indigenous communities have expressed concern that climate change and competition from non-local hunters are challenging local moose harvest opportunities. I collaborated with wildlife agencies and village tribal councils to co-design two studies to address rural community hunter concerns. The first study assessed the spatial and temporal distribution of local and non-local hunter groups to examine areas of potential competition. The second study addressed changing environmental factors and their impacts on moose harvest.

Although competition among local hunters or among non-local hunters certainly occurs, competition between local and non-local hunters, or between resident and non-resident hunters is a more common and reoccurring issue. Local hunters are those who hunt in the area in which they reside whereas non-local hunters travel away from the area they reside to hunt. I assessed hunting patterns by local and non-local hunters in a remote hunting region near the interior villages of Koyukuk and Nulato to quantify moose harvest overlap between these two user groups to assess potential competition. I used Alaska Department of Fish and Game (ADFG) moose harvest records to develop a relative competition index that identified locations and time periods within the hunting season where the greatest overlap occurred from 2000-2016. I determined that the highest competition occurred between 16-20 September (i.e., peak harvest period) and was concentrated predominantly along major rivers. To decrease overlap and mitigate potential competition between hunter groups we recommend providing information on competition hotspots to hunters, or lifting the no-fly regulation in the Koyukuk Controlled Use Area with the caveat that hunting with the use of aircraft must occur 1.6 km from the Koyukuk River corridor. These actions may provide hunters information on how to re-distribute themselves across the landscape and allow hunters to use areas away from rivers, where most harvest currently occurs.

Additionally, climate change and seasonal variability have anecdotally been documented to impact moose hunting opportunities. Specifically, warm temperatures, delayed leaf drop, and fluctuating water levels are concerns expressed by some local hunters. I quantified changes in temperature, leaf drop, and water level near Koyukuk and Nulato and the subsequent relationships between these environmental variables and the total number of moose harvested using linear regression models. I used temperature data, gauging station data (i.e., water level), remote sensing data (i.e., leaf drop analysis), and ADFG moose harvest records and explored previously untested hypotheses and to quantify relationships from 2000-2016. I concluded that non-local hunter harvest success was more dependent than local harvest success on environmental conditions. Non-local harvest significantly increased with higher water levels from 6-10 Sept ($p=0.02$), 11-15 Sept ($p=0.02$), and 16-20 Sept ($p<0.01$), and decreased with warmer temperatures in the same three time periods ($p<0.01$, $p=0.02$, $p<0.01$, respectively). Local harvest increased with higher water levels from 16-20 Sept ($p<0.01$). These results quantitatively show that environmental factors do impact hunter success. I speculate that local hunter harvest success is less dependent on environmental variability because they have the ability to harvest opportunistically, rely more heavily on the resource, and reside near the hunting area. This ability to opportunistically hunt and adapt may give them an advantage over non-local hunters as environmental conditions shift with climate change.

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## Chapter 1: Introduction

Changing social and ecological factors may be challenging moose (*Alces alces*) hunting practices and decreasing hunt satisfaction for moose hunters in Interior Alaska. I partnered with tribal councils and a wildlife management agency to form salient research questions regarding some of the factors perceived to impact moose hunting success. I worked collaboratively to design studies that addressed proposals by individuals or communities to change hunting regulations. Since 2015, 22 proposals have been submitted to the Alaska Board of Game (BOG) regarding allocation of hunting opportunities for big game or specifically moose. These proposals often attempted to limit the number of non-resident hunters, or to extend the season for resident hunters to reduce competition. However, the extent of competition between hunting groups has not been previously assessed. In collaboration with rural communities that have expressed moose hunting concerns, my overall goal was to address the extent of spatial and temporal overlap in moose harvest by local and non-local hunters to advance knowledge on important moose harvest issues and inform management decisions.

### 1.1 Background

Moose are vital to Alaska's ecosystems and considered an important cultural, nutritional, and economic resource to the public (Brown et al. 2018, Brinkman et al. 2016, Timmermann and Rodgers 2005). Annually, Alaskans harvest a mean of 7,260 moose (Titus et al. 2009) and moose hunting contributes $78 million to the state's economy (McDowell Group 2014). In 2011, 60% of Alaskan hunters targeted moose with an 18% success rate, and 31% of non-resident hunters targeted moose with a 14% success rate (ECONorthwest 2014). In remote Interior Alaska the majority of hunting occurs along navigable waterways via boats (Johnson et al. 2016, Van Lanen et al. 2012).

People hunt moose for various reasons but hunters are commonly lumped into one of two categories: subsistence hunters or recreation hunters. Subsistence is defined as the non-commercial, customary and traditional use of natural resources (Fall and Wolfe 2012). Subsistence hunters are focused primarily on providing meat for their family. Some remote communities report 90% of households use moose annually (Brown et al. 2010) indicating that subsistence is a key aspect of life. These communities tend to have high costs of living with few employment opportunities. It is increasingly common for people raised in rural communities to move to urban areas for education or employment, but return home to participate in hunting and fishing activities (Kofinas et al. 2010). Recreation hunters may be less dependent on meat as a resource and may be seeking “trophy” moose, or mature male moose (i.e., bulls) with large, symmetrical antlers. “Bagging a buck” is one of several factors that influence hunt satisfaction for white-tailed deer (*Odocoileus virginianus*) hunters (Heberlein 2002) and a multiple-satisfactions management approach is often used to create diverse hunting opportunities that emphasize the quality or quantity of harvest (Manfredo et al. 2004, Hendee 1974). Optimizing hunting opportunities often requires wildlife managers to account for sufficient abundance and seasonal distribution of game, along with sufficient access to harvest areas for a variety of human demographics (Brinkman et al. 2013).

Due to differences in values and interests, or perceived differences, between subsistence and recreational user groups it is common for hunters in one group to express concerns about the practices of the other groups. This is especially an issue between rural community residents and non-local hunters that choose to hunt near rural communities (Brinkman et al. 2018, Kofinas et al. 2010). Conflict can occur when there is direct competition for a resource, hunter density surpasses expectations (Brinkman et al. 2018), or local communities believe there is disrespectful take of an animal (Fix and Harrington 2012, Kluwe and Krumpe 2003). The level of accessibility (e.g., riverways, roads, natural corridors) may influence perceived crowding because limited access can concentrate hunters and increase encounter rates (Brinkman et al. 2018, Shelby et al. 1989). Therefore, it is important to account for varying levels of accessibility because of the potential effects on extent and frequency of hunter overlap.

Moose hunting in Alaska is regulated under a dual federal-state management system. The state maintains “equal access” for all Alaskan residents, whereas the federal system may give hunting preference to rural residents on federal lands. A checkerboard of land jurisdictions creates complex regulations. Regulations are formed to mitigate sociopolitical and biological concerns (Bath 1995) and are usually set prior to the start of the hunting season. In-season management does not exist for the majority of moose hunts. Drawing permits can be used to limit hunter densities, harvest rates, and hunter distribution in areas of management concern (G. Stout, personal communication).

Amplified climate change and seasonal weather variability in Alaska are also influencing hunter opportunities (Cold et al. 2018, Brinkman et al. 2016, Overland et al. 2014, ACIA 2005).

Rapid environmental change is challenging communities that rely on local natural resources to address nutritional and cultural demands, and to offset high costs of living (Brinkman et al. 2016). However, the impacts of environmental changes on moose hunting are not well documented. Anecdotally, hunters have raised concerns that environmental changes are challenging moose hunting opportunities. These concerns inspired proposals for regulation change to the BOG. From 2001-2008, 8 proposals were submitted to the BOG or the Federal Subsistence Board requesting extensions to the moose-hunting season due to warming autumns (McNeeley 2012). Previous research recommended that managers adopt less rigid management practices to ensure that rural communities can better adapt under the pressure of climate change and seasonal variability (McNeeley and Shulski 2011).

### 1.2 Motivation: CPS Framework

The Community Research Partnerships (CRP) for Supporting Sustainable Traditional Harvest Practices framework was core to the production, importance, and completion of this thesis. CRP is a program at UAF dedicated to creating healthy researcher-community partnerships that co-design and implement the research agenda to generate mutually beneficial, locally relevant, and useable science. My research embraced this approach. My research was a collaborative effort among University of Alaska Fairbanks (UAF), Alaska Department of Fish and Game (ADFG), Tanana Chiefs Conference (TCC), the Council of Athabascan Tribal Governments (CATG), and village Tribal Councils. Collaboration, or co-production of knowledge, helps create usable science that may benefit the adaptation of local communities (Dilling and Lemos 2010). Usable science is research that is designed so results can be used directly in policy or management decisions, or for building local adaptive capacity. Working in collaboration with communities to form local adaptation strategies can benefit their self-reliance (Chapin et al. 2016). Self-reliance and community well-being are vulnerable to climate change, and one of the key vulnerability indicators is the ability to provide the required amount of subsistence resources to meet an individual, a family, or a community's nutritional and cultural needs (Ozkan and Schott 2012).

I partnered with Nulato Tribal Council (NTC), Koyukuk Traditional Council (KTC), and ADFG to study social and ecological factors influencing perceptions of hunter competition and moose harvest success. Nulato and Koyukuk are located in the Yukon Middle Koyukuk region, approximately 270km west of Fairbanks, and are predominantly Koyukon Athabascan (population = 270 and 70, respectively). These communities are disconnected from the road system, have higher than average rates of unemployment, and higher than average costs of living (US Census 2010). NTC and KTC independently guided my research objectives, determined their magnitude of involvement with my study, and provided input and feedback throughout the duration of the project. An important aspect of this project was an emphasis on providing results in a meaningful and understandable format to each research partner. This included informal community reports and infographics, technical papers for ADFG, and scientific publications.

By collaborating with Nulato and Koyukuk, I aim to build local self-reliance, decrease their vulnerability to changing social and ecological systems, and enhance their community's well-being. Wildlife managers may be able to incorporate results into future management decisions to help reduce hunter competition, and maintain or increase hunter satisfaction. This research may also be useful for providing policy makers or citizens with objective and defensible data to support important management and policy decisions.

## 1.3 Research Questions and Overview

This thesis comprises two chapters focused on the impacts of social and environmental factors on moose hunting noted as concerns by NTC and KTC. Chapter 2 focused on *social concerns* expressed by NTC and KTC. These social concerns regarded the scope and magnitude of moose harvest by non-local hunters within traditional hunting areas around rural communities that creates potential for competition with local hunters. Local hunters are defined as people who harvest a moose within the hunting unit (i.e. Game Management Unit) they reside and non-local hunters are defined as people who harvest a moose outside of the hunting unit they reside. I explored hunting activity in an urban and a rural hunting region using ADFG moose harvest records from 2000-2016. I further investigated the spatial and temporal overlap of local and non-local hunters in the rural hunting region to identify points of competition. This latter step was accomplished by developing a hunter competition index that incorporated non-local hunter density and local hunter proportion across the landscape around the communities. This competition index may have utility in other regions where competition exists for other species of wild game.

Chapter 3 focused on *environmental concerns* expressed by NTC and quantified changes in temperature, leaf drop, and water level, and the subsequent impacts on moose harvest success from 2000-2016. Hunters have expressed concerns regarding the impacts of changing environments on moose hunting (McNeeley and Shulski 2011). Specifically, they were concerned that during the hunting season 1) warmer fall temperatures were decreasing moose movement and increasing chance of meat spoilage, 2) rapidly fluctuating water levels were creating unreliable access to preferred hunting sloughs, and 3) delayed leaf drop was occurring more often, thus reducing moose sightability during the hunting season. These factors are all perceived to add challenges to moose harvest during the regulated hunting season and impact harvest opportunities. This chapter used remote sensing (i.e., leaf drop analysis), temperature, river gauging station (i.e., water level), and ADFG moose harvest data to examine associations with moose harvest success. Hunters were categorized as "local hunters" or "non-local hunters", and I hypothesized that environmental changes (i.e., temperature, water level height, date of leaf drop) would impact these groups differently due to differences in hunting methods. This research explored BOG proposal arguments and previously untested hypotheses about the effects of temperature, leaf drop timing, and water level on moose harvest success.

## 1.4 Broader Relevance

Research has examined the impacts of climate on ecosystems for decades but this research was typically performed with a top-down approach. The top-down approach is research formed by agencies or institutions typically without the consultation or guidance of local residents to form research questions. Although, the top-down approach is often beneficial because it includes outside perspectives, is broadly applicable, and is well funded, a bottom-up approach, or research designed at the local level, has the ability to prioritize salient research questions and address unique local concerns. Collaborative research has been proposed to target the downfalls of solely top-down research in order to better understand the impacts of a warming climate on local populations of people (Meadow et al. 2015). The CRP framework may serve as a template for future collaborative research efforts as it is ideal for researchers seeking to expand the adaptive capacity of communities through scientific investigations that are locally relevant.

Although this thesis focused on moose hunters in Alaska, managers and hunters in different regions with different species may find certain aspects of this research useful. This research may be particularly salient to other communities in Interior Alaska. Many communities in the Yukon River Basin struggle with the same concerns as Nulato and Koyukuk in regards to moose harvest (Brown et al. 2016, Brown and Koster 2015, Brown and Kostick 2015). These communities tend to have predominantly indigenous populations (n<500), are disconnected from other communities by lack of road systems, contain similar habitats and climates, rely on mixed cash-subsistence economies, and share similar cultures. The competition index can be applied in other situations where competition or overlap between user groups exist, a global wildlife management problem. Harvest of wild game in other parts of the world often occurs in areas with higher road density or within short distances to roads (Hayes et al. 2002, Fuller 1990) and therefore the inclusion of a hunting access component is likely pertinent. Lastly, very few studies have addressed the impacts of environmental factors on harvest success, and with current climate projections it may become increasingly important to assess relationships between harvest and rapid environment change to maintain hunter satisfaction and opportunities.

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## Chapter 2: Assessing moose harvest patterns to address hunter competition


### 2.1 Abstract

Moose are an important resource in Alaska to many different user groups. Because of the high demand for a limited supply of moose, competition among user groups exists and is common. However, few data exist on the characteristics of moose hunter competition. To address this hunter concern and knowledge gap, we used moose harvest data (2000-2016) to quantify and compare hunting patterns across time and space among different user groups in different moose management areas. Specifically, our objectives were to: 1) quantify harvest patterns over time in regions with low (roadless rural) or high (roaded urban) accessibility, and 2) quantify overlap in harvest patterns of different hunter types (local, non-local) in rural regions to assess areas of potential competition. We created a relative competition index that accounted for the spatial and temporal distribution of both local and non-local harvest. We identified differences between harvest timing in rural and urban hunting regions, with urban and rural regions experiencing peak moose harvest during beginning and middle of the season, respectively. In the rural region our rural hunter competition scores ranged from 0-0.106, with mean score 0.01 (SD=0.02) and median score 0.003 across the UCUs and was highest during 16-20 Sept. We found that 50% of local harvest occurred in 33% of the rural hunting area and that 54% of non-local harvest occurred in 18% of the rural hunting area. To minimize competition, we recommend creating strategies for redistributing hunters away from[1] high-use areas, allowing aircraft transportation of moose hunters to remote lakes 8 km from the Yukon and Koyukuk Rivers, or providing information to hunters on known competition hotspots. Our relative hunter competition index can be used by wildlife managers in other regions for other game species where hunter competition creates management dilemmas.


### 2.2 Introduction

Hunter satisfaction is an important metric of the performance of a game management program. Managers regulate hunter activities and maintain wildlife populations to optimize hunt opportunities and maximize hunt satisfaction (Ericsson 2003). Research has shown that

[1] Hasbrouck, T.R., T.J. Brinkman, G. Stout, and K. Kielland. Assessing moose harvest patterns to address hunter competition. Prepared for submission to *Alces*.

maximizing hunter satisfaction requires more than providing sufficient animal densities (Hammitt et al. 1990). In addition to abundant game, hunters have also expressed that the number of other hunters seen, or perceived crowding, are important factors of hunt satisfaction (Heberlein and Kuentzel 2002). These findings support the multiple-satisfactions-approach-based management that recognizes that multiple factors contribute to the extent of hunt satisfaction (Hendee 1974). Satisfaction declines when hunters perceive crowding or competition with other hunters (Shelby and Heberlein 1986). Conflict can occur when the spatial and temporal overlap among hunters surpasses expected hunter densities (Brinkman et al. 2018). Conflict also can arise when hunters compete with other hunters who exhibit, or are perceived to exhibit, hunting values and motivations that do not align with local societal norms (Fix and Harrington 2012). This is relevant for rural communities that may perceive that non-locals do not understand or respect traditional culture and practices of locals (Kluwe and Krumpe 2003). Additionally, competition for preferred size or age class of animals can also be a point of conflict (G. Stout, personal communication).

Local concern over competition for game with non-local hunters has been an ongoing policy issue for wildlife managers. We define competition as the interaction between user groups for moose or for hunting space, either of which may be limited or perceived to be limited. Competition is exacerbated when hunter groups are in the same area at the same time due to higher potential for direct encounters. Conflict between hunter groups can result from both competition and perceived differences in value systems. Proposed solutions to competition are often related to changes in the allocation of hunting opportunities. Since 2015, a total of 22 proposals were submitted to the Alaska Board of Game requesting changes in statewide or regional allocation of big game among hunter user groups (ADFG 2016a). Many of the proposals (n=12) focused specifically on moose (*Alces alces*) and describe how local hunters are concerned that non-local hunters are taking too many moose and creating excessive competition. The extent of competition has not been objectively assessed. Better information on distribution of hunting patterns of different stakeholder groups may provide insight on the extent of competition and inform potential solutions. Our research addresses this data gap by quantifying harvest patterns and overlap across space and time among different hunter groups (local and non-local) and across different hunting regions (accessible urban and inaccessible rural). It is important to address moose hunter competition in Alaska because it may result in reduced hunt satisfaction or hunt success (Fix and Harrington 2012, Heberlein and Kuentzel 2002). It may increase the time and effort required for harvest, therefore hunting expenses (e.g., fuel costs), which is particularly salient to rural communities with relatively weak cash economies (Brinkman et al. 2014). Assessing characteristics of conflict may help better define the problem, enhance communication, and inform resolution on some of these issues (Decker and Chase 1997).

Moose are of critical nutritional, cultural, and economic importance to Alaska residents (Northern Economics Inc. 2006, Timmermann and Rodgers 2005). People hunt moose for many reasons including for the meat, to spend time with family and friends, to interact with nature, fulfilling traditions, or for the trophy opportunity (Brinkman et al. 2018). During 1987-2007, an average of 29,000 hunters killed 7,260 moose annually in Alaska (Titus et al. 2009). Annually, moose is used by >90% of rural Interior Alaska community households (Brown et al. 2010) and attributes over $78 million to the state's economy (McDowell Group 2014).

With so much interest, importance, and investment in moose hunting, federal and state agencies create moose hunting regulations to sustain moose populations while optimizing diverse hunting opportunities. Alaska Department of Fish and Game (ADFG) divides the state into 5 management regions and then further into 26 Game Management Units (GMU). Some of these GMUs are subdivided into subunits, allowing for more precise management of different wildlife populations. Hunting season length and timing are often based on biological events (e.g., rut, calving) and accessibility for local hunters (G. Stout, personal communitcation) (Fig. 2.1). Management seeks to mitigate both biological and sociopolitical issues (Bath 1995). Regulations are complex, and differ in space and time. Contradicting the Alaska Constitution that ensures equal access to fish and wildlife for all Alaskans, the Alaska National Interest Lands Conservation Act of 1980 (ANILCA; P.L. [Public Law] 96-487) mandates that hunting and fishing priority be given to rural Alaskans on federal land. Regulations for 'recreational hunting' maximize individual opportunity, whereas 'subsistence regulations' aim to provide opportunities to address rural communities' harvest needs (McCorquodale 1997).

Although hunting opportunities exist for diverse interests of many stakeholder groups, conflict from competition and perceived differences in value systems among groups still occurs. Competition is common between local and non-local hunters, or between resident and non-resident hunters (Brinkman 2014, Kluwe and Krumpe 2003). Non-residents are hunters who live outside of Alaska, local hunters are residents who hunt in the same GMU where they reside, and non-local hunters are residents who travel outside of the GMU they reside to hunt. Most hunting in Alaska occurs on public land, and many hunters use the same areas year after year and set up hunting camps and informal territories on public land (Brinkman 2018, Johnson et al. 2016). Hunting motivations vary by individual, but local rural hunters place a high significance on meat provision whereas non-resident and non-local hunters may be more motivated by novel experiences, trophy opportunities, or meat provision. It is also common for people born in rural communities to move to urban areas for education or employment but return home to hunt (Kofinas et al. 2010). This hunter demographic is potentially problematic because they become non-local by our definition but may actually continue to be viewed as local by fellow local hunters. Additionally, these hunters may list either urban or rural addresses in hunt reports, adding confusion to our defined hunter groups.

In addition to comparing different hunter group types, it is also important to consider how hunting patterns may change in different hunting regions. Regions with different levels of accessibility may have hunters with different perceptions of acceptable levels of crowding (Shelby et al. 1989). Researchers have suggested that regulations and hunting opportunities may be optimized by using an "availability framework" which uses hunter accessibility, game abundance, and seasonal distribution of game to inform local management decisions (Brinkman et al. 2013). Accessibility is a central logistical challenge to hunting in remote parts of Alaska. In order to understand hunting patterns, we must take into account the accessibility that different regions provide. It is possible that hunting patterns in urban regions, or those areas with road systems, relatively high human populations, and low unemployment rates, exhibit different hunting patterns than those who hunt in rural regions, or locations disconnected from road systems with higher unemployment rates. Identifying differences in patterns between regions with good and poor access may provide insight on strategies for optimizing management in those areas. Research in other locations has found that harvest increases within close proximity to roads (Fuller 1990) or in areas with higher road densities (Hayes et al. 2002). For example, easily accessible regions in Alaska are more likely to be managed using drawing permits (limited) rather than general harvest permits (unlimited) to reduce hunting pressure and competition (Woodford 2014).

The goal of our research was to explore aspects of competition in management areas with different accessibility options and between different hunter types by examining temporal and spatial overlap. Our objectives were to: 1) quantify harvest patterns over time in regions with low (roadless rural) or high (roaded urban) accessibility, and 2) quantify harvest patterns of different hunter types (local, non-local) in rural regions where competition is more frequently expressed. By comparing local and non-local hunting patterns, our study addressed the spatial and temporal characteristics of user group issues that have not been extensively studied among moose hunters in Alaska. From our analysis, we located the time and location of overlap and generated an index of competition. Our effort may help inform a management approach that reduces tension among hunters and optimize hunter satisfaction. Also, our hunter competition index may be applicable for other game species in other regions where competition is perceived as a management issue.

## 2.3 Study Area

We examined hunting patterns in GMUs 20, 21, and 24 (Fig. 2.2) in Interior Alaska. The main ecotype in Interior Alaska is the boreal forest and comprises white spruce (*Picea glauca*), black spruce (*P. mariana*), birch (*Betula papyrifera*), aspen (*Populus spp*), and willow (*Salix spp*). Additionally, the area contains low-lying wetlands mottled with lakes, low scrub bogs, herbaceous meadows, and forb-herbaceous marshes. Intense winters and summers create annual temperatures ranging -40°C to 22°C respectively (Brabets et al. 2000).

To examine differences between rural and urban hunting regions we compared three GMU subunits with high accessibility near Fairbanks: GMU 20A, 20B, and 20D, to two subunits with relatively low accessibility approximately 250 km west of Fairbanks near Koyukuk: GMU 21D and 24D. Although these two regions have relatively similar habitats they have vastly different social systems, infrastructure, and defining characteristics (Table 2.1), as well as moose and predator population dynamics. These subunits were selected because of the importance of moose hunting in each region despite their differences in social systems and infrastructure.

### *High Access Study Region*

The urban region (GMU20 subunits) is situated around Fairbanks North Star Borough and is road-accessible. Hunters in this area may use road vehicle, ATV, watercraft (motorized or man-powered), or aircraft to access their moose hunting area (Brinkman et al. 2018). This GMU is subdivided into many smaller hunt areas with unique regulations that can change by year. As an example, in 2017 this GMU had 64 different sets of regulations for moose harvest (ADFG 2016).

Regulations included antlerless moose hunts, any bull hunts, and antler or brow-tine restriction hunts. In 2016, 6,222 hunters harvested 1,550 moose (25% success rate) (ADFG 2018).

*Low Access Study Region*

The rural region (GMU 21D and 24D) is along the Yukon and Koyukuk Rivers and consists of 35 Uniform Coding Units (UCUs) (Fig. 2.3). UCUs are the finest spatial resolution available to assess hunter harvest and therefore we used the UCU scale to assess overlap among hunter groups. The Koyukuk Controlled Use Area (KCUA; 12,408 km²) straddles the northern GMU 21D and the southern GMU 24D. Although moose hunting occurs across the entirety of this study region, the majority (especially among non-locals) occurs within the KCUA. In other communities on the Yukon River, essentially all hunters travel and hunt by boat (Johnson et al. 2016). We used the KCUA because there is a mandatory ADFG check-in station on the Koyukuk River and reporting rate is thought to be high compared to other rural areas. All hunters coming from the lower Koyukuk River are required to stop at this check-in station, so there is comprehensive hunter and harvest information for the past 20 years in the KCUA. Access to this hunting region for non-locals requires a considerable logistic effort and expense. A hunter from Fairbanks would have to drive 220km north on the Dalton Highway to the Yukon River Bridge and then travel by boat 483km down the Yukon River to get to Galena, AK near the mouth of the Koyukuk River.

In 2017, there were 10 types of moose hunting regulations across our low access GMUs (Table 2.2) (ADFG 2016b). Under the subsistence registration hunt, residents can shoot any bull but are required to render the antlers unusable for trophy consideration by cutting one palm of the antler in half. The antler destruction regulation was created to emphasize harvest for meat rather than trophy value (G. Stout, personal communication). Residents have the opportunity to apply for a drawing permit that would allow them to shoot any size bull and keep the antlers intact. Non-residents can only participate in a hunt if they receive a drawing permit. Although they do not have to destroy the antlers, they can only shoot bulls with a minimum of 4 brow tines on at least one antler or with antler spreads >127 cm. In 2016, 756 hunters harvested 375 moose (50% success rate) (ADFG 2018).

## 2.4 Methods

### *Collaborative Research*

Our research was part of a larger project, UAF's Community Research Partnerships (CRP) for Supporting Sustainable Traditional Harvest Practices. Through this larger project, individual studies are designed to work collaboratively with communities to design objective, relevant, important research related to hunting and fishing practices. Two entities, Koyukuk Traditional Council and Nulato Tribal Council, in the rural GMUs partnered with us to address local research priorities relating to hunter competition.

### *Hunter Database*

Moose harvest estimates were provided by ADFG. Although mandatory harvest reporting exists, harvest data may not be complete due to underreporting (Schmidt et al. 2015). However, the proportion of incomplete reporting is thought to be relatively low in our study areas. Also, ADFG harvest data represent the best available information on hunter patterns. We assumed that the hunters who reported successful hunts are representative of all successful hunters within the GMU with respect to location of harvest, hunt patterns, and effort. Non-successful hunters do not report fine-resolution details, such as when and where they hunted, so our analysis is limited to hunters that successfully harvested a moose. We acknowledge that unsuccessful hunters contribute to and are affected by hunter competition. However, with hunter success rates being consistent across time and space, we assume patterns of successful hunters serve as an adequate index of all hunters.

We analyzed all harvest data during the September hunting season from 2000-2016. We included the following harvest data fields in our analysis: permit type (drawing or registration hunt), hunter residency, success (yes or no), date of kill, number of days spent hunting, and hunt location. Data that were missing hunter residency or date of kill were excluded from the dataset. Antlerless hunts and hunts that occurred outside the normal hunting season (i.e., September) were not assessed. These hunts are not comparable between the study regions and factors influencing harvest may introduce bias or inaccuracy in our results. Our dataset included 25,113 moose harvest records.

*Analysis*

We used statistical packages in R Studio to compare hunting patterns among study regions and user groups (RStudio Team 2015). We calculated the proportion of local harvest and non-local harvest in each UCU in the rural hunting region to assess if hunters were equally distributed across the landscape and to assess if locals and non-locals used the same hunting areas. ESRI ArcGIS was used to map and visualize the distribution of different hunter groups.

First, we pooled local and non-local hunters to calculate the density of hunters within each UCU across the landscape. We used Eq. 1 to assess potential competition between hunter groups by calculating a relative competition index for each UCU by multiplying non-local hunter density and local hunter proportional use. Due to the low number of non-resident hunters and the similarity of patterns, we pooled these hunters with non-local resident hunters. We used river length (Hydrology 1:1000000) within each UCU to estimate the area accessible to hunters because nearly all hunters in the rural GMUs access their moose hunting areas by watercraft (Johnson et al. 2016). We assessed each UCU with this equation and ranked each UCU in order of highest relative competition index. ESRI ArcGIS was used to visualize each UCU's relative competition index.

In our model, an increase in non-local hunter density within a specific UCU will cause an increase in the relative competition index score, mediated by the level of importance of that UCU for local hunters. For example, a UCU with a high non-local hunter density that also has high importance to local hunters will have a higher score than a UCU with a high non-local hunter density that has low importance to local hunters. ESRI ArcGIS was used to map and visualize the competition index by UCU.

$$\left(\frac{\text{\# Non-Local Hunters}}{\text{Cumulative River Length (km)}}\right) \text{X} \left(\frac{\text{\# Local Hunters}}{\text{Total Local Hunters}}\right) = \text{Relative Competition Index}$$

Eq. 1

*Temporal and Spatial Overlap in Rural Hunting Region*

To assess changes over the entire study period we compared two time periods: 2000-2008 and 2009-2016. This split allowed us to simply assess if there was a shift over time. Due to non-normal distribution, we used paired Wilcoxon signed ranks tests to assess changes in UCU use for local and non-local hunters between the two study periods. We used unpaired Wilcoxen signed ranks tests to quantify the differences between local and non-local hunters use in each UCU for each time period. We repeated the relative competition index analysis for each time period and compared results to understand if the severity or location of highest competition changed over time. We examined the proportional UCU use for each hunter type (local, and pooled non-local and non-resident) for the early and late time periods to assess changes in space within user groups over time.

To assess competition within the hunting season we split the hunting season into 5 equal time periods (i.e., 1-5, 6-10, 11-15, 16-20, and 21-25 Sept) and generated a relative competition index for each UCU by 5-day periods across the full study period. This step was essential to help understand when during the hunting season competition was at its highest. Grouping in 5-day intervals also fostered samples sizes adequate for statistical analysis. To fully understand competition it would be necessary to know hunter effort (i.e., time spent in the field hunting for moose), however, this data is currently limited and potentially flawed.

## 2.5 Results

### *Temporal Differences among Urban and Rural Hunting Regions*

From 2000-2016, 5,692 and 19,423 moose were harvested in the rural and urban regions, respectively. The urban and rural study regions exhibited different date of kill distributions with differences in date of peak harvest (Fig. 2.4). Peak harvest occurred at the beginning of the season in the more accessible urban region, and during the middle of the season in the rural region. Local hunters (n=2,286) and non-local hunters (n=3,156) in the rural region had similar harvest temporal patterns (Fig. 2.4) suggesting overlap among hunter groups across the hunting season.

### *Spatial and Temporal Overlap in Rural Hunting Region*

In the rural hunting region, local and non-local hunter types exhibited different proportional use of UCUs (Fig. 2.5 and 2.6). Fifty percent of local harvest occurred in 33% of the rural hunting area, whereas 54% of non-local harvest occurred in 18% of the rural hunting area. Hunter competition scores ranged from 0-0.106 with mean score 0.010 (SD=0.02) and median score 0.003 with high levels of competition existing in 12% of the GMU, moderate in

8% of the GMU, and minimal in 80% of the GMU (Fig. 2.7). Twenty-seven UCUs had competition scores less than the mean, 4 UCUs had competition scores ranging from 0.011-0.014, and the UCUs with the highest competition scores had values of 0.033, 0.051, 0.054, and 0.106. Hunter land use and therefore competition was largely concentrated in UCUs with major rivers that facilitate hunter access.

Non-local hunter spatial distribution did not change from the early (2000-2008) to the late study (2009-16) periods (p=0.70) but local spatial distribution did change (p=0.02). Local hunters decreased their proportion of use in 5 UCUs and increased their proportion of use in 4 UCUs. The relative competition index showed that competition by 5-day periods within each UCU ranged from 0-0.017 with mean 0.0005 (SD=0.0016), was highest 16-20 Sept (Fig. 2.8).

## 2.6 Discussion

Our analyses suggested that rural and urban hunting regions exhibit different distributions of date of kill. The urban hunting region exhibited a spike following the opening of the moose-hunting season, followed by a steep decline, and then a moderate increase near the middle of the season. After the middle of the season, harvest rates rapidly declined which may be partly a result of regulations ending at different dates (i.e., Sept 15, 20, 25, 30). These seasons provide different opportunities for archers, rifle hunters, residents, and non-residents in different sub-regions. Plausible reasons for peak harvest during the beginning of the season may be related to good access for relatively high volumes of hunters trying to harvest a limited supply of legal moose before someone else does or simply because of “opening day syndrome.” Research on other species has attempted to assess factors influencing the day of kill. Lebel et al. (2012) found that higher levels of access increased the number of harvested white-tailed deer. Hansen et al. (1986) determined that white-tailed deer harvest was most closely associated with day of hunting season. Fobes (1945) claimed that higher harvest was attributable to clear days with minimal precipitation. Rivrud et al. (2014) found that red deer harvest increases on weekends and moon phase. We further believe that warmer weather early in the season could create more comfortable hunting conditions for urban hunters less reliant on a successful annual harvest. Or, the beginning of the season encompasses Labor Day weekend, which provides hunters with an extra day off work (important in urban region where employment is high relative to remote communities).

We speculate that patterns of hunting in rural regions are driven more by biological and environmental conditions than in accessible urban area with high hunter volumes. Relatively lower hunter numbers may afford hunters the opportunity to align their effort with ideal environmental conditions. Bulls generally become more active in mid-September as they approach the rut (Joly et al. 2015). Also, cooler temperatures later in September facilitate meat preservation in remote regions where there might be several days between harvest and when the meat can be processed and frozen. Lower ambient temperatures are important because meat will begin to spoil at 4.4°C (USDA 2011). Lastly, locals have suggested that hunting moose becomes easier after the leaves fall from the trees along the river (Appendix A). This increases sightability of moose along river networks and sloughs used for hunting. Due to low employment rates, local hunters may be less limited by work schedules or holidays, and therefore may possess greater flexibility across the season in selecting hunting dates.

Competition in rural regions occurred more often later in the month, aligning with peak harvest. Low competition during the beginning of the season could be due to inferior weather conditions causing decreased hunt success or decreased local participation. Local hunters may have more flexibility on hunting dates during the season whereas non-local hunters likely choose their hunting dates in advance of the season because of the substantial time and effort needed to access the area. Also, some draw permits shorten the hunting season for non-resident hunters, therefore artificially bounding when harvest must occur.

To assess competition, it may be important to consider other factors than simply non-local density and local proportion. High non-local to local ratios and closer proximity to communities may increase the probability that a local hunter will encounter a non-local hunter, thus exacerbating the perceptions of competition and crowding. Local hunters are generally more tolerant of other local hunters (Brinkman et al. 2018). Examining Fig. 2.2 may help distinguish key hunting areas for local hunters. High number of non-local hunters in these key hunting areas may result in conflict without scoring high on the competition index. Additionally, "unexpected" overlap or the occasion where hunters expected solitude in a location but encountered other user groups, may increase hunter conflict. The number of hunters who were raised in this rural hunting region and moved to urban areas is not known. This group of hunters may skew the level of competition and therefore the presence of conflict. As this phenomenon continues it may be prudent for management agencies to assess the impacts on wildlife populations.

Our research supports the idea that availability framework should be used to assess hunting opportunities (Brinkman et al. 2013). Following the availability framework, our findings suggest that along with moose abundance and distribution, it is critically important to account for hunter access when exploring how hunting systems function. Due to the reliance on waterways we used cumulative total river length within each UCU to determine hunter density, however, other regions could include road length, travel corridor length, or overall area. Tensions with non-local hunters are often discussed as issues by rural communities but the magnitude and scope of such tensions have not been assessed. This research directly provides information on previously untested hypotheses for communities and management agencies. Additionally, we created a generalizable relative hunter competition index that can be recreated for different regions and game species. This equation allows managers to include local data to understand where competition may be greatest within their region. This competition index does not include a temporal component and it is important for researchers to assess the relative competition score for time periods that make sense within their region of interest.

Our ability to assess hunter competition was limited by the data that hunters provide when completing hunt reports. We were unable to assess non-successful hunter effort because that information is not recorded. In order to fully understand competition and hunter satisfaction, we recommend that more data be collected from non-successful hunters after their hunt. Additionally, in order to limit the amount of hunter dissatisfaction we recommend focusing efforts on distributing hunters away from areas with a relatively high competition index, especially during later parts of the hunting season. Considering the plausible asymmetrical nature of competition, it may be more prudent to dilute the number of non-local hunters in UCUs near communities, although this may be impossible with current regulations and stipulations in the Alaska constitution. Current regulations prohibit the use of aircraft for transportation into the GMU, and we suggest lifting that limitation with the caveat that aircraft use must occur 1.6km from the Yukon and Koyukuk River corridors. This may help increase distribution across the landscape and provide unique opportunities for non-local hunters away from local hunters that seldom use airplane transport or travel greater than 1.6km off a navigable river. Another potential solution would be to provide data regarding these harvest hot spots to hunters so that hunters have information to actively decide to avoid areas with historically high hunter densities. Emphasizing that hunters can distribute themselves away from these zones of “high competition” may help hunters to select areas with “lower competition.” Ultimately, both individual hunters and agencies will need to take on responsibility to alleviate completion in order to maintain hunt satisfaction.

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2.8 Figures

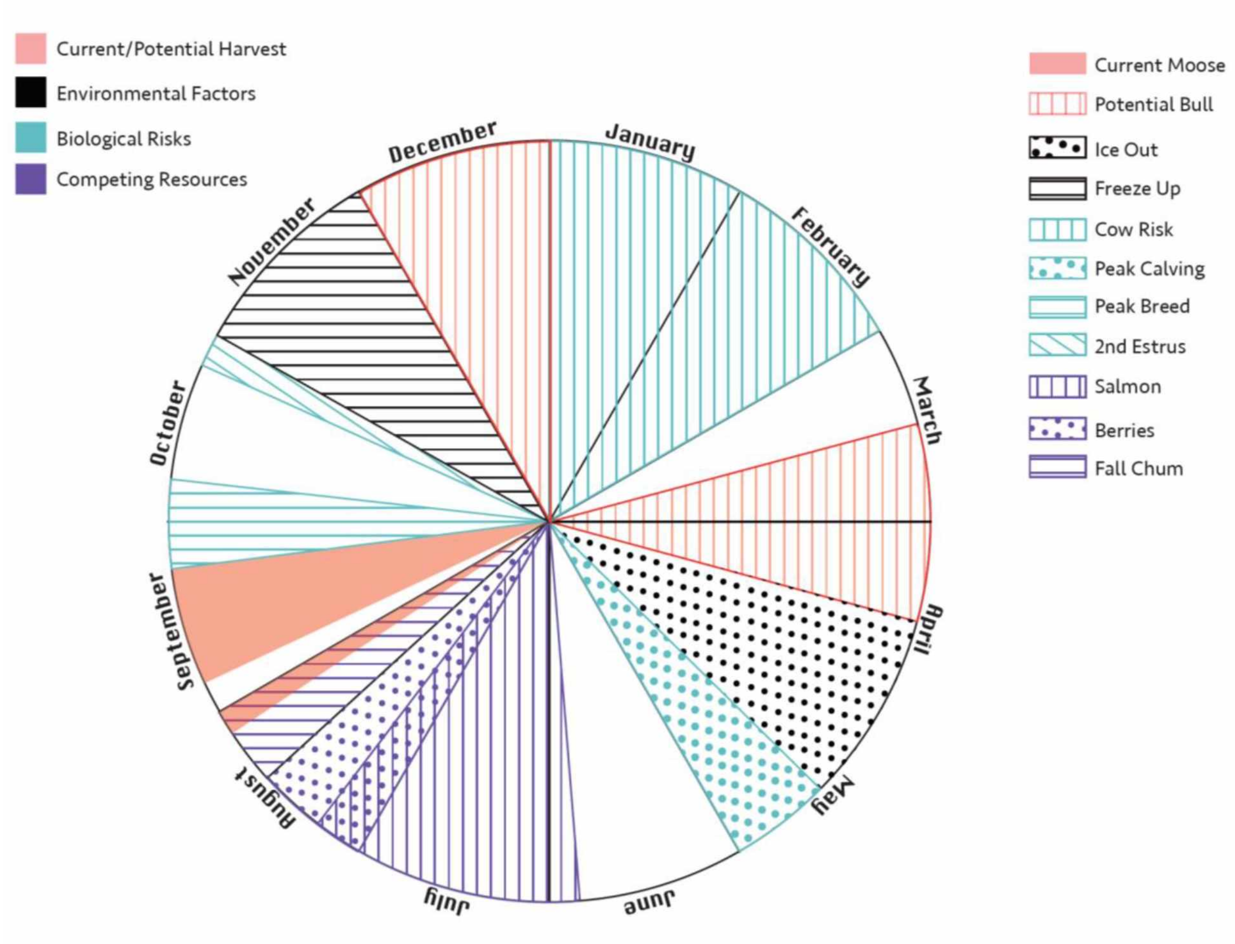


Figure 2.1. Round calendar depicting current moose hunting season and potential hunting seasons in red. Blue represents regions during the year that a hunting season could yield biological risks to populations. Black represents time periods that would have dangerous environmental conditions for hunters. Purple represents time periods that local hunters are likely busy with other subsistence practices. Calendar data provided in part by G. Stout.

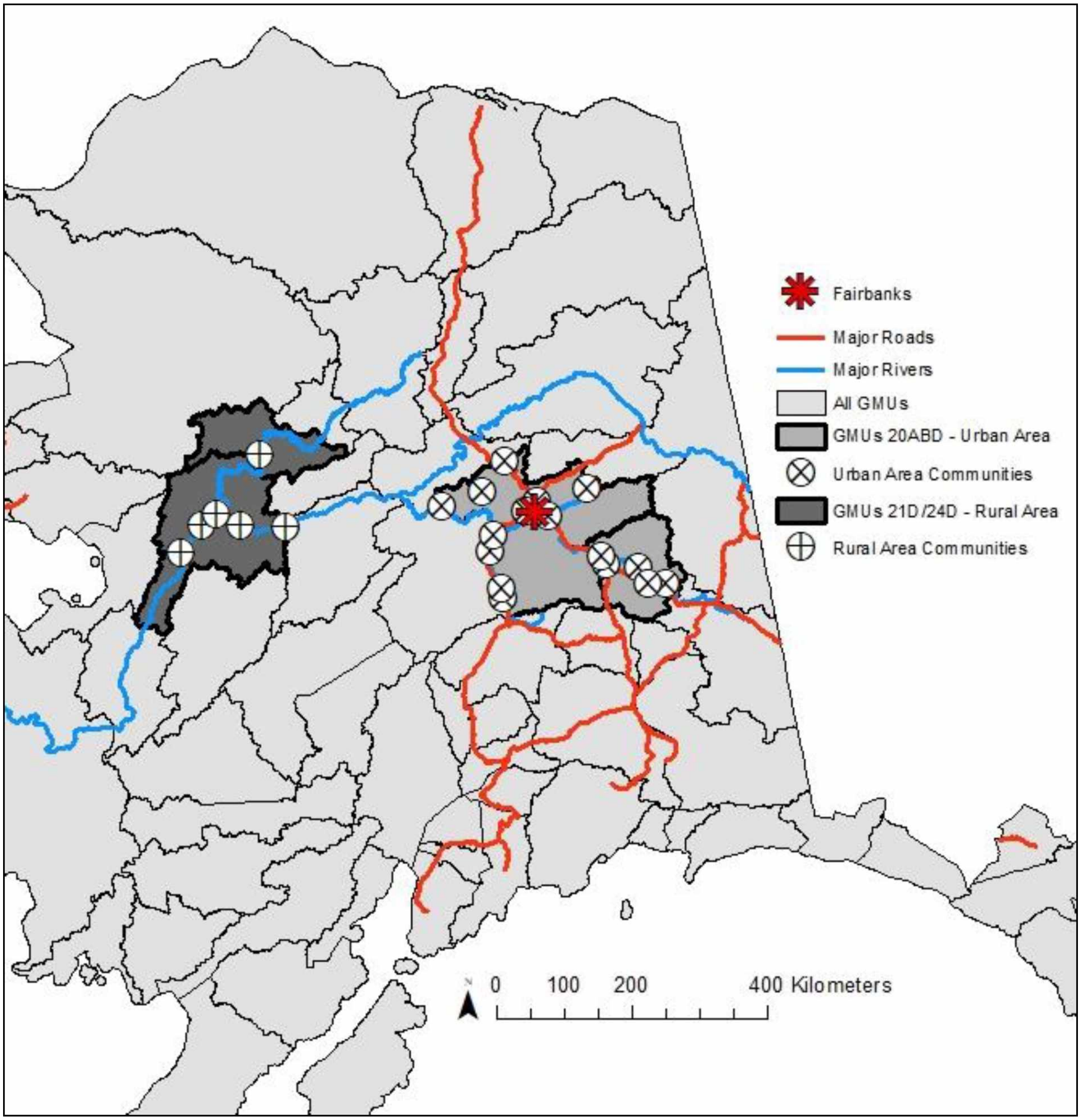


Figure 2.2. Map of project study area depicting the rural and urban moose hunting regions.

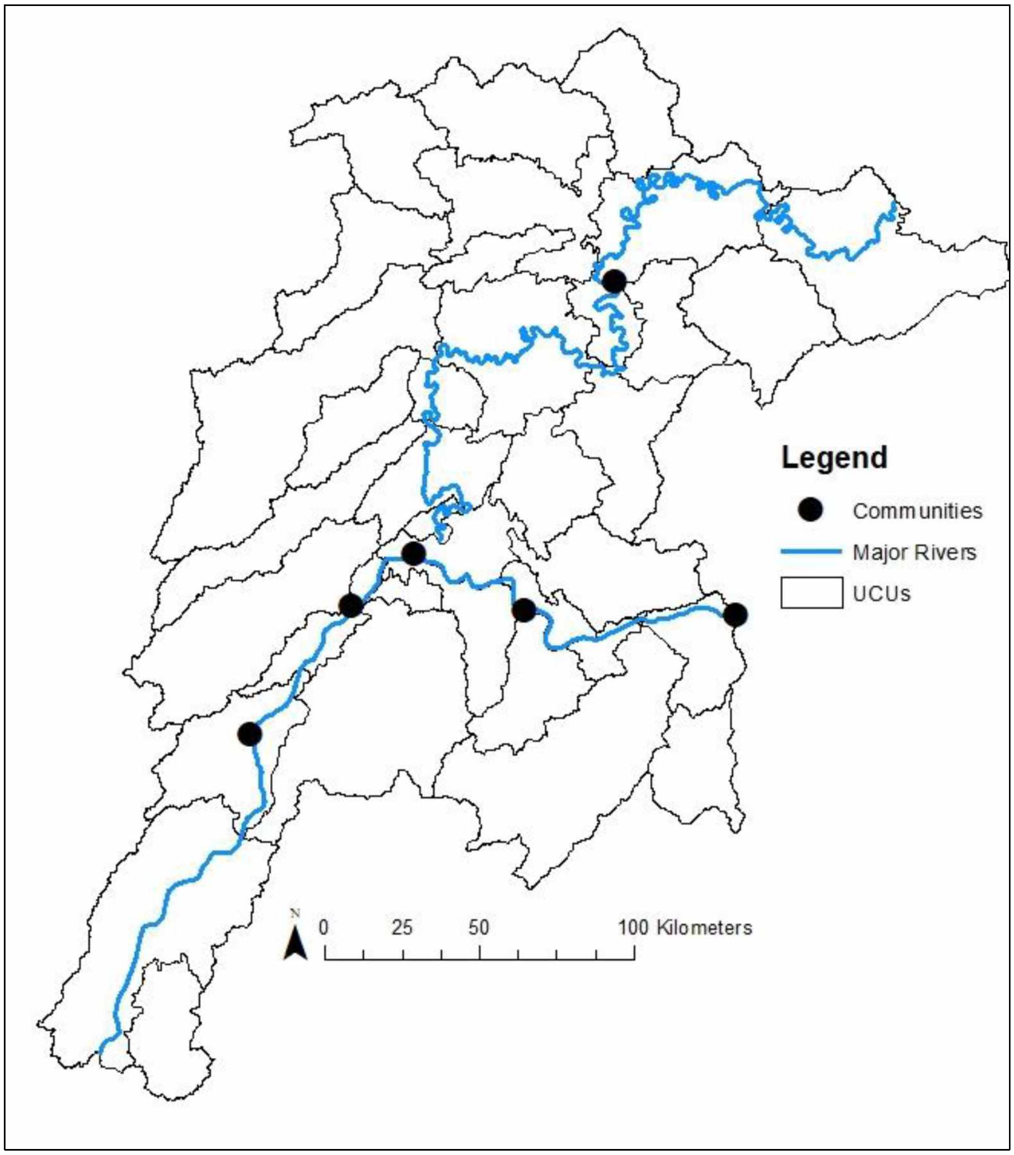


Figure 2.3. Map of Uniform Coding Units (UCUs) with Game Management Units 21D and 24D.

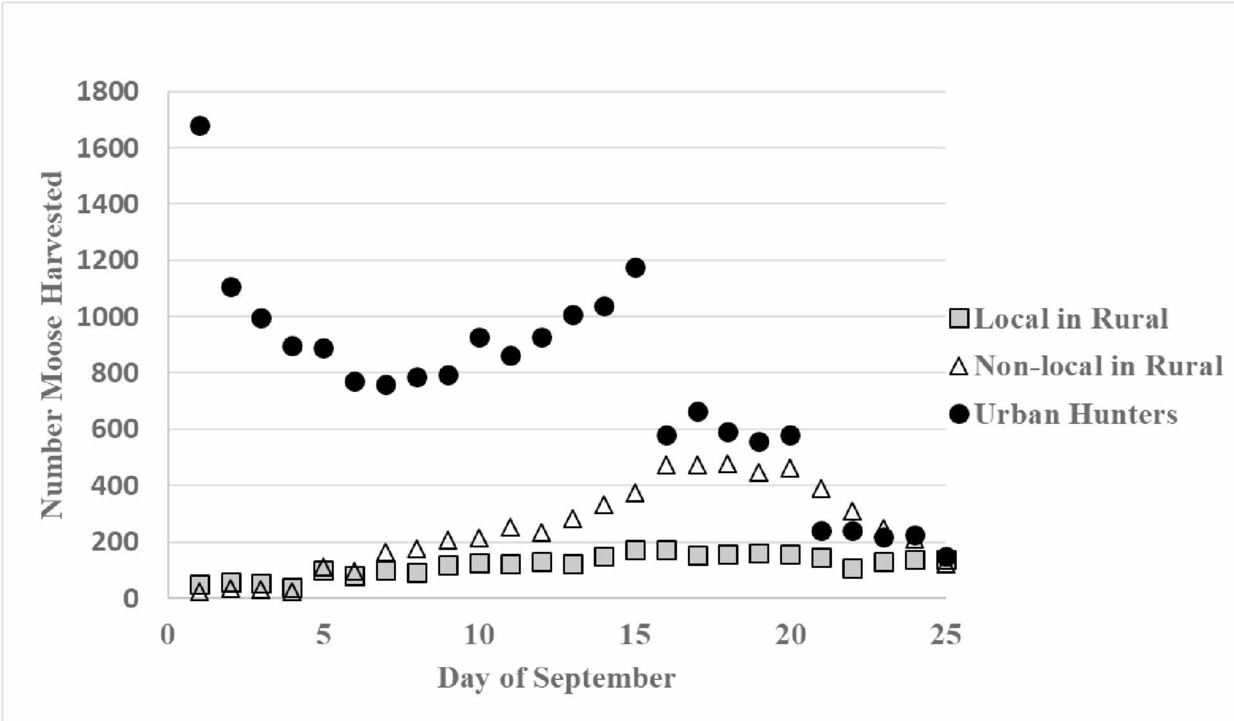

Figure 2.4. The total number of moose harvested from 2000-2016 by day hunters in an urban hunting region, and by local and non-local hunters in a rural hunting region

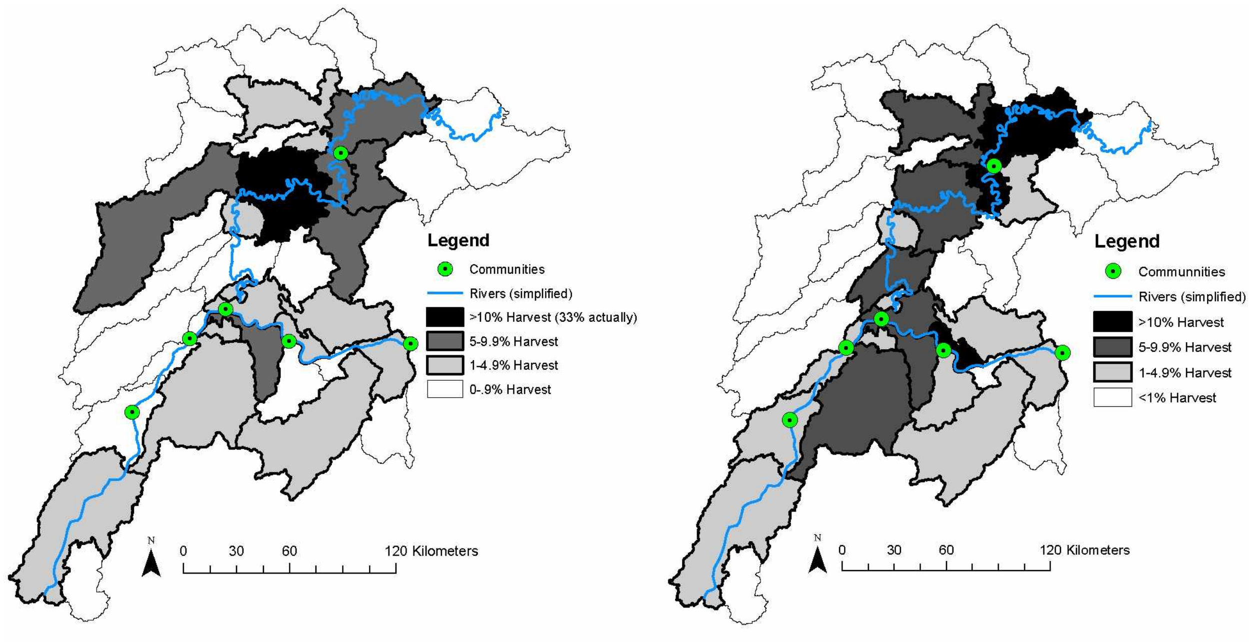


Figure 2.5. Non-local (left) and local (right) percent harvest by UCU within the rural hunting region from 2000-2016.

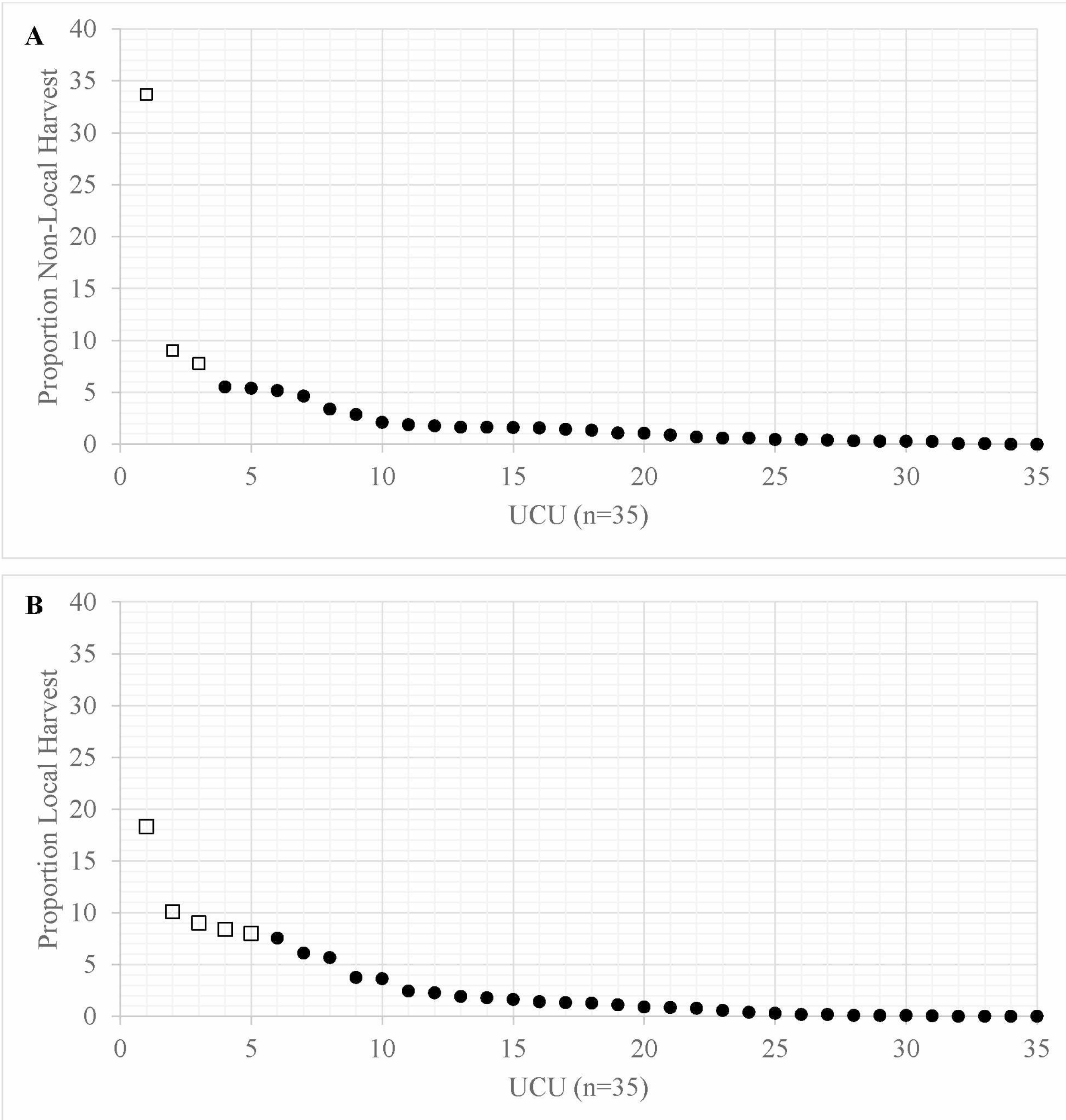


Figure 2.6A&B. Proportion of use of UCUs within the rural hunting region by local hunters (A) and non-local hunters (B). X-axis refers to the most used UCUs for each hunter type and not a specific sub-area, therefore UCU value 1-35 does not necessarily correspond to the same location for local and non-local hunters. Data points displayed as boxes sum together to constitute 50% of harvest for local hunters (n=5) and non-local hunters (n=3).

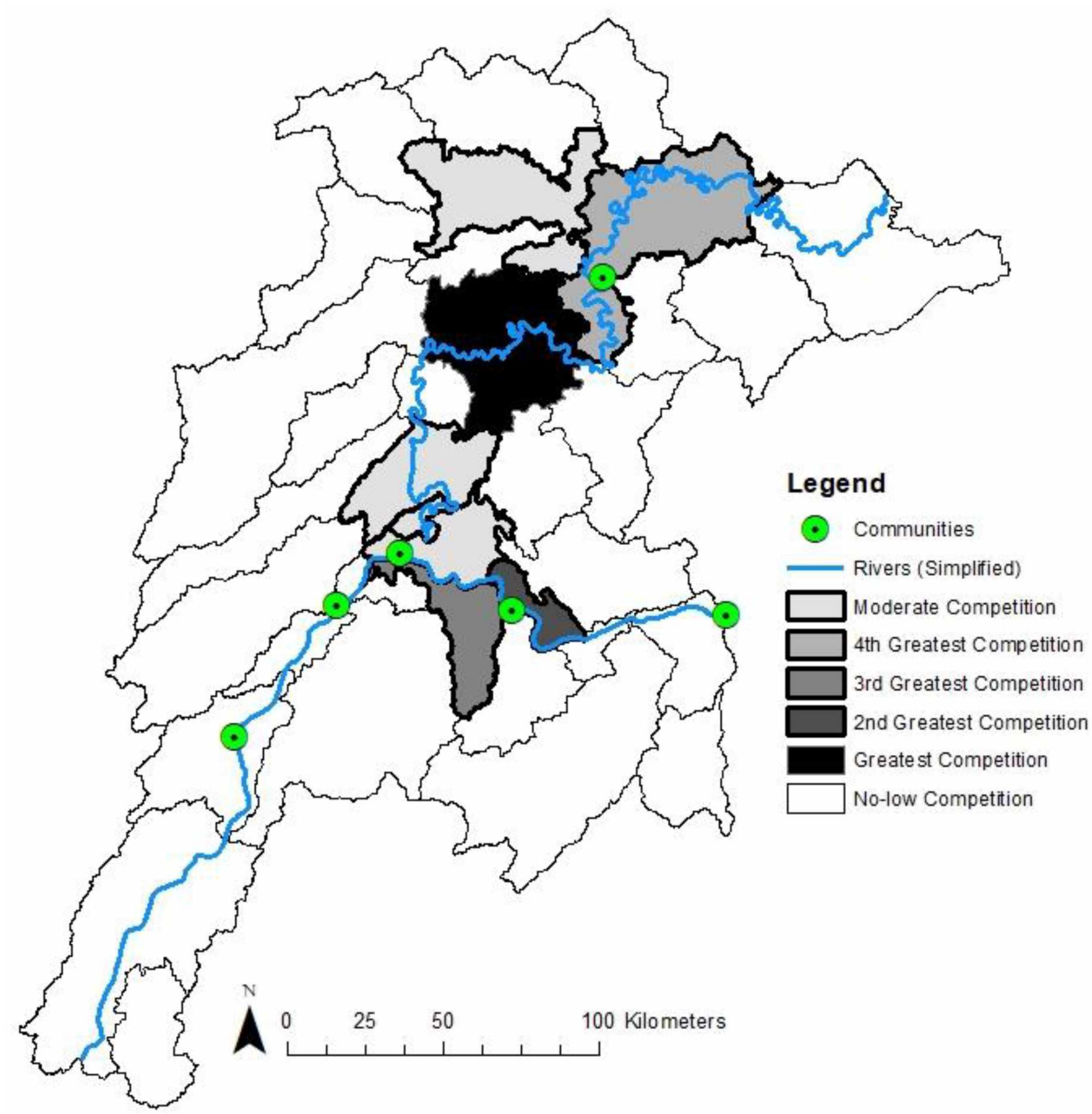

Figure 2.7. Depiction of UCUs with the top 4 highest competition scores, moderate competition scores, and no to low competition scores.

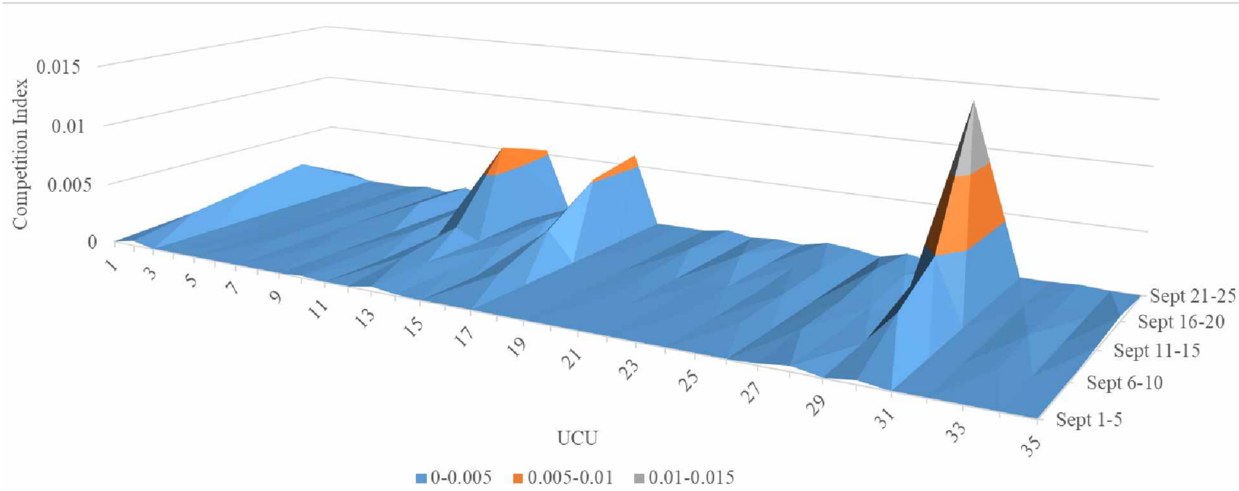


Figure 2.8. 3D plot showing when and where competition is greatest between local and non-local hunters in a rural hunting region. X-axis refers to individual UCUs, y-axis refers to hunter competition scores, and z-axis refers to time period within the hunting season. Colors help visualize scores.

## 2.9 Tables

Table 2.1. Difference in area, census, density, highway availability, and employment rate for the urban and rural study region. Census and employment rate was created by U.S. Census Bureau 2011.

| | Urban Region | Rural Region |
|---|---|---|
| Area ($km^2$) | 34,600 | 28,000 |
| Census (2000) | 104,079 | 1,461 |
| Density ($km^2$/# people) | 0.33 | 19.16 |
| Highway length (km) | 737 | 0 |
| Unemployment rate | 7% | 20% |
| # of moose hunting Regulations (2017) | 64 | 10 |

Table 2.2. Regulations in rural hunting region in 2016 (ADFG 2016b). Permit types are registration (RP) or drawing (DP), and residency types are residents (R) or non-residents (NR).

| GMU | Permit Type | Residency | Special Instruction | Open Season |
|---|---|---|---|---|
| 21D/24D, within KCUA | RP | R | Any bull, destroy antler | Sept 1-Sept 25 |
| | DP | R | Any bull | Sept 5-Sept 25 |
| | DP | NR | Antlers ≥127 cm, OR ≥4 browtines on one side | Sept 5-Sept 25 |
| 21D, outside KCUA | RP | R | Any bull, destroy antler | Aug 22-Aug 31, Sept 5-Sept 25 |
| | DP | NR | Any bull | Sept 5-Sept 25 |
| | DP | NR | Antlers ≥127 cm, OR ≥4 browtines on one side | Sept 5-Sept 25 |
| 21D, east of KCUA | DP | R | Any bull | Sept 5-Sept 25 |
| | DP | NR | Antlers ≥127 cm, OR ≥4 browtines on one side | Sept 5-Sept 25 |
| 24D, remainder | RP | R | Any bull, destroy antler | Sept 5-Sept 25 |
| | DP | R | Any bull | Sept 5-Sept 25 |
| | DP | NR | Antlers ≥127 cm, OR ≥4 browtines on one side | Sept 5-Sept 25 |

## Chapter 3: Quantifying effects of environmental factors on moose hunting success in Interior Alaska

### 3.1 Abstract

Recent climate change is causing rapid changes to the environment in Alaska. Some of these changes, such as rising temperatures, extended growing seasons, and fluctuating water levels, may impact hunters who rely on moose (*Alces alces*) as a subsistence resource. Hunters have expressed concern that hunt success is being challenged due to warmer temperatures altering moose behavior, delayed leaf drop decreasing sightability, and low water levels limiting access to hunting areas. These changes have not been quantitatively assessed and the environmental impacts on moose harvest success were not well understood. We assessed annual changes in 1) temperature, 2) leaf drop date, 3) water level used for access to hunting grounds, and 4) impacts of these changes on local and non-local moose hunter effort and success in Interior Alaska. We used satellite imagery, weather station data, and river gauging station data to assess changes in environmental factors as well as Alaska Department of Fish and Game's moose harvest records from 2000-2016. We used simple linear regressions to estimate associations between environmental factors and our dependent variables, the number of moose harvested and the annual date of peak harvest. We found no relationship between leaf drop and local or non-local hunter harvest ($p=0.61$, $p=0.81$ respectively). We estimated a positive relationship between daily water level and non-local harvest for 6-10 Sept ($p=0.02$), 11-15 Sept ($p=0.02$), and 16-20 Sept ($p<0.1$), and an inverse relationship between mean daily temperature and non-local hunter harvest for the same dates ($p<0.01$ $p=0.02$, $p<0.01$), respectively. Local hunters increased the number of days they hunted over time ($p=0.02$) and harvest had a positive relationship with water levels from 16-20 Sept ($p<0.01$). This research provided information on previously untested hypotheses regarding the impacts of environmental conditions on moose hunter harvest.[2]

### 3.2 Introduction

Rapid global climate change is impacting the availability of local wild resources that northern communities rely on for nutrition and culture (Brown et al. 2018, Brinkman et al. 2016).

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[2] Hasbrouck, T.R., T.J. Brinkman, E. Trochim, G. Stout, and K. Kielland. Quantifying effects of environmental factors on moose hunting success in Interior Alaska. Prepared for submission to *Journal of Wildlife Management*.

The Arctic is warming at twice the rate of the global average (ACIA 2005) and is expected to continue to undergo major changes in the upcoming decades (Overland et al. 2014). Communities in Interior Alaska documented a 3.7-4.8°C increase in mean annual temperatures and a 1.1-2.7°C increase in mean autumn temperatures from 1949-2015 (Alaska Climate Research Center 2018). Across Alaska, rising temperatures are altering permafrost depth and thaw rates (ACIA 2005), evapotranspiration rates (Hinzman et al. 2005), growing season lengths (Wendler and Shulski 2009), precipitation rates (Stewart et al. 2013), sea levels (Maslowski et al. 2012), coastal erosion (Markon et al. 2012), and wildfire regimes (Johnstone et al. 2010, Kasischke et al. 2010). These factors interact and create complex feedbacks to global processes (Hinzman et al. 2005) causing direct effects on ecological processes.

Changes in ecological processes can have significant impacts on ecosystem services, defined as the benefits that nature provides to humankind (Daily 1997). Ecosystem services are particularly important in Native communities in rural Alaska, where residents nutritionally and culturally rely on local subsistence resources (Wolfe and Walker 1987; Johnson et al. 2009). Subsistence resources are commonly known as wild resources used for customary and traditional purposes. These nutritional resources provide sources of essential nutrients that are not commonly consumed when eating commercially available foods (Bersamin et al. 2006). To decrease chronic disease associated with marketplace foods researchers have recommended that rural communities should consume more traditional food sources that limit the intake of calories and trans fats, and increase the consumption of fiber-rich foods, key minerals, and vitamins (Johnson et al. 2009). As an example, Omega-3 fatty acids are found in higher quantities in game meat (26-104 fatty acids/100 grams of meat) than grain-fed beef (16 fatty acids/100 grams of meat) (Medeiros et al. 2002). In addition to providing beneficial nutrients, consuming wild resources is more economically feasible than purchasing commercial foods and can help ensure social and cultural well-being (Loring 2010). Wild foods commonly available for communities in interior Alaska include berries, salmon (*Oncorhynchus spp.*), non-salmon fish, waterfowl, bear (*Ursus spp.*), caribou (*Rangifer tarandus*), and moose. Considering that survival was historically reliant on food acquisition, Native communities formed tightly knit cultural and spiritual relationships with wild resources (Reeves and McCabe 2007). Sharing and trading resources was a key component for Alaska Native cultures and this practice is still exhibited today (Brown et al. 2010).

In many Interior Alaskan communities, moose is one of the most important subsistence species. In 2007, more than 1.5 million kg of moose meat was harvested in Alaska and 90% of this remained within the state (ADFG 2018). For example, in Nulato, a rural community in Interior Alaska, 90% of households report using moose meat during the year (Brown et al. 2010). Moose hunting is regulated by both state and federal agencies. These regulations are complex, occasionally confusing, and differ by region of the state and sometimes year (ADFG 2016). Hunting season length, timing, and quotas are based on the timing of biological events (e.g., rut, calving, antler drop) and estimated moose populations. Moose hunting season is typically 1-25 September with some variation depending on location and hunt type.

During recent decades, rural communities that rely on moose meat have expressed concern about the effects of a changing climate on moose harvest opportunities (Brinkman et al. 2016). Communities have reported that changes in the growing season length (i.e., later leaf drop) and autumn water level height are influencing their moose hunting opportunities (McNeeley and Shulski 2011, McNeeley 2009). Communities have submitted proposals to the Alaska Board of Game requesting changes in regulations due to climate-related factors (Appendix A). However, changes in temperature, leaf drop timing, and water levels during the hunting season have not been quantified, nor has the association between these variables and harvest success. Therefore, our objectives were to quantify trends in these variables and estimate impacts of these variables on moose hunting success in Interior Alaska. Alaska Board of Game proposals, Native community concerns, and qualitative research indicate that more rigorous quantitative research on the impacts of environmental conditions on moose harvest is needed to inform moose management (McNeeley and Schulski 2011). Our research quantified previously untested hypotheses using a mixture of publicly available data and remote sensing techniques. To our knowledge, this study represents the first quantitative estimate of the association between moose harvest success and environmental change, and represents one of the few assessments of environmental factors on game harvest.

*Temperatures*

Interior Alaska's mean annual temperature has warmed on average -15.9 - -15.3°C from 1949-2015 (ACRC 2016). Continued warming may have negative effects on moose populations by increasing heat stress (Lenarz et al. 2009). Moose are a cold-climate species and therefore exhibit stress or decreased health at higher ambient temperatures. Renecker and Hudson (1986) found that winter temperatures exceeding 5°C and summer temperatures exceeding 14°C cause increased metabolism, heart rate, and respiration rate in moose. Wind speed, habitat, and an individual's physical health also contribute to heat stress (McCann et al. 2013). Moose were found to respond to warm temperatures by selecting more densely vegetated areas (Melin et al. 2014, Demarchi and Bunnell 1995). Moose will also 'bed down' in thermal refuges during warmer temperatures, therefore decreasing movement (McCann et al. 2016). In some parts of their geographic range, moose will respond to warm temperatures by decreasing diurnal activity and increasing nocturnal activity (Dussault et al. 2004) and moose in Nova Scotia were documented to alter behavior with temperature increases (Broders et al. 2012). In Interior Alaska, bull moose exhibit the greatest level of movement from 19-25 Sept (Joly et al. 2015). Additionally, warmer temperatures cause meat to spoil more rapidly. Research completed in Sweden found that hunters voluntarily did not hunt during warmer days to decrease the occurrence of meat spoilage (Ball et al. 1999). Hunters in Interior Alaska expressed the same concerns, and may select cooler days for hunting. In Alaska, however, most information compiled on the association between climate and the availability of fish and game has been qualitative or anecdotal (Brinkman et al. 2016).

*Leaf Drop*

Warming temperatures are lengthening growing seasons in latitudes 40-70 °N causing changes in spring (i.e., leaf out) and fall (i.e., leaf drop) phenology (Marchland et al. 2004) but locations within these latitudes are changing at different rates. Growing season length received significant research attention globally but with limited site-specific research on end of season changes in boreal Alaska. Green-up dates are occurring about 6 days earlier in the past 80 years in northern Alaska (Swanson 2017), and 13 days earlier in the past 30 years in Eurasia's boreal forests (Li et al. 2017). However, attempts to quantify growing season length change have been completed in several large-scale regions. In the past 30 years the end of the growing season has extended 9.4 days in North America (Jeong et al. 2011), 5 days in boreal Eurasia (Li et al. 2017), and 8.6 days in latitudes >45°N (Park et al. 2016).

Changes in leaf drop are more difficult to quantify because fall senescence is influenced by several factors: water stress (Delpierre et al. 2012), water availability (Forkel et al. 2014, Fu et al. 2014), temperature (May et al. 2017), precipitation (Liu et al. 2015), and elevation and latitude (Rozenstein and Adamowski 2017). Leaf senescence also is highly species-specific (Springer et al. 2017, Panchen et al. 2014) and therefore landscape level timing of leaf drop is not ubiquitous. Although growing season length has been assessed to some degree, the change of leaf drop in Interior Alaska has not been documented.

Extended growing seasons and delayed leaf drop dates are causing challenges for hunters because trees with leaves provide cover for game and obstruct hunter sightability (BOG Proposal 94 2017). Forest type has been shown to affect a person's visibility of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) (Brinkman et al. 2009) and white-tailed deer (*O. virginianus*) (Sage et al. 1983) and logically extends to other forest ungulates such as moose. If the timing of senescence is changing in Interior Alaska then wildlife managers may need to consider potential impacts on hunting opportunities. Or, hunters will need to adapt to the changing environment by shifting hunting locations, hunt strategies, or temporal choices related to hunting effort. Indigenous communities show a high capacity for adapting to changes in the environment (Kofinas et al. 2010) and were actively adapting to these changes for generations; however, hunters were not restricted by regulated hunting seasons prior to the 20th century.

*Water Levels*

Water levels have been assessed at local, and now more recently, global levels, and have increased or decreased in different areas. Globally from 1984-2015 we have lost 90,000 $km^2$ of water bodies but gained 184,000 $km^2$ of new permanent water bodies in different locations (Pekel et al. 2016). Water levels across Interior Alaska have received a significant amount of research and findings suggest that some areas gained and other areas lost surface water. Research in subarctic Alaska found that shrinking ponds were linked to melting permafrost and increased evapotranspiration rates (Riordan et al. 2006) and research in south-central Alaska concluded 80% of field sites across the Kenai Peninsula were undergoing drying events (Klein et al. 2005). Lakes that are not undergoing terrestrialization (the process of changing from water to land) in boreal ecosystems in Alaska are influenced by permafrost presence and steeper banks with low surface to volume ratios, whereas disappearing lakes are characterized by encroaching vegetation, increased water temperature, and shallow depths (Roach et al. 2011).

Many Interior Alaska communities are situated along the Yukon River or one of its many tributaries. The majority of moose hunting occurs along these waterways because it is suitable moose habitat and because the use of watercraft is an effective method for locating and transporting moose (Johnson et al. 2016). Low river levels cause decreased access to sloughs and shallow tributaries of the Yukon River. In previous research, communities reported reduced water levels during the moose-hunting season (August and September) (Wilson et al. 2015). Climate-related changes in access to hunt areas were found more important than game abundance or distribution of wildlife populations (Brinkman et al. 2016) and therefore, reduced access to hunting grounds may negatively influence harvest success.

### 3.3 Study Area

Our study was conducted in Interior Alaska near the Indigenous community of Nulato, (Fig. 3.1). This community was selected because of their involvement in a larger research project entitled Community Research Partnerships for Supporting Sustainable Traditional Harvest Practices. This program was designed to allow communities to form salient and relevant research questions pertinent to their local concerns. Nulato (pop = 271) is a Koyukon Athabascan community along the Yukon River about 480 km west from Fairbanks. Nulato is located in Game Management Unit (GMU) subunit 21D and is adjacent to the northern unit of the Innoko National Wildlife Refuge. GMUs are subregions (n=26) in the state that are designated and managed individually (or in clusters) by Alaska Department of Fish and Game (ADFG) to maintain sustainable wildlife populations while providing hunting opportunities. In 2010, Nulato residents reported that access to preferred hunting areas was limited in recent years due to low water levels (Brown et al. 2010). Other communities within this area include Koyukuk, Kaltag, Galena, Ruby, Huslia, and Hughes. The communities are isolated and disconnected from the road system. Due to high costs of living, as well as cultural preferences, residents rely on a mixed cash-subsistence economy (BurnSilver et al. 2016). The region is located in a boreal forest ecosystem at the juxtaposition of two ecoregions: Interior Bottomlands, and Interior Forested Lowlands and Uplands. The area supports typical boreal species: white spruce (*Picea glauca*), black spruce (*P. mariana*), birch (*Betula neoalaskana*), aspen (*Populus spp.*) forests, low to tall willows (*Salix spp.*), and wetlands mottled with oxbow lakes and thaw lakes comprised of low scrub bogs, herbaceous meadows, and forb-herbaceous marshes. The area experiences short, warm summers and long, cold winters with annual temperatures ranging from -40°C to 22°C (Brabets et al. 2000).

Moose became well established this region in the 1930s and the Koyukuk controlled use area (KCUA) was established in 1978. The KCUA was formed due to the accelerating demand by hunters for a high moose density with large bulls and relatively easy boat access. The KCUA typically has more moose and more hunters than other parts of GMU 21D and therefore ADFG created the Koyukuk moose checkpoint station, a mandatory stop for all people hunting in the KCUA. Wildlife agencies manage the KCUA and the remainder of GMU21D and 24D with different regulations. A geospatial population estimate (GSPE) conducted in 2011 in the KCUA estimated 6,379±957 moose. In 2014, GMU 21D had 8,749±1300 moose. In 2015, the checkpoint station documented 211 local residents, 205 non-local Alaska residents, and 10 nonresident hunters attempting to harvest moose in the KCUA. A total of 237 bull moose were harvested by 111 locals, 119 non-locals, and 7 nonresidents, with success rates of 53%, 59%, and 70%, respectively (Stout 2018).

The annual number of non-local hunters decreased in the early 2000s as a result of a regulation change that was created to stabilize the harvest. The number of local hunters apparently increased over time but this was likely a result of increased reporting rates rather than increased harvest rates. “Failure to report” regulations were implemented statewide in 2004 and harsh consequences helped increase reporting rates (Stout 2016).

## 3.4 Methods

### *Temperature Analysis*

We used daily mean, maximum, and minimum temperature data from the National Oceanic and Atmospheric Association (NOAA 2018). These data were collected in Galena, Alaska (60 km east of Nulato), the only community within the GMU with a long-term weather station. We used a simple linear regression to assess changes in daily mean, maximum, and minimum temperature from 2000-2016 during the hunting season. We used mean temperature during the hunting season and during the week of peak moose harvest within each year. For example, if peak harvest occurred on 16 Sept then we calculated the average temperature from 12-20 Sept.

*Leaf Drop Analysis*

We used Google Earth Engine (GEE), an online geospatial analyzing program (Gorelick et al. 2017), to analyze fall phenology from 2000-2016 in our study area. GEE overcame limitations (e.g., cloudiness, geometric distortion from sun angles, data storage) that previously hindered this type of research in northern regions. GEE is a cloud-supported system that has not been used to address hunting issues. Although GEE requires programming skills it is a beneficial tool because it is easy to update on demand, is accessible to a variety of users, and analysis can easily be altered with new data. Other geographic regions (e.g., Africa and S.E. Asia) have used GEE methods (Xiong et al. 2017a, Xiong et al. 2017b, Goldblatt et al. 2016, Patel et al. 2015) but it has rarely been used in northern regions.

To assess fall phenology during moose-hunting season we used Moderate Resolution Imaging Spectroradiometer (MODIS) imagery from 20 Aug - 29 Sept (on non-leap years) to calculate Normalized Difference Vegetation Index (NDVI), a common proxy for vegetative productivity (Rouse et al. 1974). We calculated NDVI using imagery from the Aqua Surface Reflectance Daily L2G dataset (MYD09GQ) and the Terra Surface Reflectance Daily L2G imagery (MOG09GQ) dataset by manipulating Band 1 (red, 0.62-0.67 μm) and Band 2 (near infrared, 0.841-0.876 μm). We masked water using the Global Surface Water dataset. We summed and averaged all pixels across the landscape to determine the landscape average NDVI on every DOY within our study period. Days with flawed imagery due to clouds received NDVI values that were interpolated from NDVI values from the day before and the day after the particular image. Research in a cool-temperate deciduous broad-leaved forest in Japan found that peak leaf drop, or when 50-73% of leaves had fallen from trees, was associated with NDVI values of approximately 0.6 (Nagai et al. 2014) and therefore we used this NDVI value as our index for leaf drop. Additionally, Filippa et al. (2018) found this value to be representative of NDVI during the shoulder season. For each year, we flagged the DOY that exhibited NDVI below 0.6 as the date of peak leaf drop. Simple linear regression was used to assess the trend in leaf drop date over time. We calculated the long-term mean date of leaf drop and used confidence intervals to identify years as early or late leaf-drop years.

*Water Level Analysis*

We used data from the United States Geological Survey water gauge station on the Yukon River in Galena, Alaska to assess water level. The gauging station records water level as meters above sea level. Galena has been recording river depth since 1971. We used a simple linear regression to examine the change in water levels across each hunting season and between hunting seasons to understand the seasonal and temporal variations that may be influencing harvest. We looked at the mean water level during the hunting season and during the week of peak harvest within each year. As an example, if peak harvest occurred on 16 Sept then we calculated the average water level from 12-20 Sept. Years with river levels one standard deviation below the long term average were categorized as “low” and years with water levels one standard deviation greater than the long term average were categorized as “high.” We assumed that increase or decrease in water level caused a similar shift in tributaries and we acknowledge that this does not take into account other factors that affect access into sloughs (e.g., riverbank erosion, sedimentation).

*Relationships among Environmental Change and Moose Harvest*

We used ADFG moose harvest data collected from 2000-2016. We conducted analyses on a fine scale (daily) and on a coarse scale (annual). On the coarse scale analysis we used the total number of moose harvested and the temperature (mean), water level (m elevation), and leaf drop status (early, average, or late) as predictor variables. We used simple linear regressions to quantify relationships between environmental factors and moose harvest success for local and non-local hunters. We assessed these hunter groups independently because regulations and hunt strategies are different for these hunter groups.

For the fine-scale analysis, we examined the daily temperature and daily water level on daily moose harvest. Considering leaf drop is an annual event, we were unable to examine the impacts of fall senescence on daily harvest. We split local and non-local hunters to address differences in hunter types and used simple linear regressions to assess the relationships between the number of moose harvested per day and leaf drop, daily temperature, and daily water level. We hypothesized that lower water levels, higher temperatures, and later leaf drop resulted in lower moose harvest. We further hypothesized that local and non-local hunters would not be equally impacted by environment parameters. Non-locals select their hunting dates before the hunting season, whereas most local hunters can decide during hunting season because of their closer proximity to the hunting area (better access because of shorter travel distances between their home and hunting area), and therefore we speculated that environmental conditions would impact them differently.

## 3.5 Results

### *Environmental Changes*

We did not identify a trend in the linear relationship for average mean (7.7±0.8°C), maximum (12.4±1°C), and minimum (2.9±1°C) daily temperatures in our study area from 2000-2016 ($p=0.68$, $p=0.59$, and $p=0.99$, respectively) during moose-hunting season (Fig. 3.2). Leaf drop timing varied across our study period (Fig. 3.3) but did not significantly change ($p=0.18$, $R^2=0.12$). We identified 2000, 2001, 2004, 2012, and 2016 as years with late leaf drop at the landscape level and 2002, 2009, 2010, 2011, 2013, 2014, and 2015 as early leaf drop years. The remaining years did not differ from the long-term average (Julian Day 243±1.2) peak leaf drop date. The water level of the Yukon River at the Galena Gauge Station averaged 32.2±0.29m above sea level from 2000-2016 during the moose-hunting season but did not exhibit an annual linear trend over time ($p=0.19$, $R^2=0.06$) (Fig. 3.4). We identified 5 low years, 6 average years, and 5 high years using our classification system. One year (2002) did not have water level data.

### *Environmental and Harvest Relationships – Annual Analysis*

We found no significant relationships between environmental variables and total annual local hunter harvest. There was not a measurable relationship between leaf drop date and non-local total harvest ($p=0.84$, $R^2=0.00$). Total annual non-local harvest was positively associated with water level ($p<0.01$, $R^2=0.57$) (Fig. 3.5), and almost significantly inversely associated with high temperatures ($p=0.06$, $R^2=0.21$) (Fig. 3.6). An annual mean temperature increase of 1°C was associated with 6.9 fewer moose harvested annually by non-local hunters and an annual mean water level increase of 1m was associated with 49.8 more moose harvested annually by non-local hunters.

*Environmental and Harvest Relationships – 5-day Analysis*

We found no relationships between total local harvest and water level or mean temperatures from 1-15 Sept or 21-25 Sept. Total local harvest was positively related to water level from 16-20 Sept ($p<0.01$, $R^2=0.13$) and nearly negatively related to high mean temperatures from 16-20 Sept ($p=0.09$, $R^2=0.03$). We determined approximate peak harvest occurred 16-20 Sept. Total non-local harvest was not significantly related to any environmental parameter from 1-5 Sept or 21-25 Sept. Total non-local harvest was positively related to high water levels during 6-10 Sept ($p=0.02$, $R^2=0.08$), 11-15 Sept ($p=0.02$, $R^2=0.09$), and 16-20 Sept ($p<0.01$, $R^2=0.18$) and negatively related to mean temperatures for the same time periods ($p<0.01$ and $R^2=0.10$, $p=0.02$ and $R^2=0.06$, and $p<0.01$ and $R^2=0.15$, respectively). All statistical results are reported in Table 3.1.

## 3.6 Discussion

Contrary to previous research we did not identify a linear relationship between our environmental variables and year in our study region. However, a lack of change in annual mean values during the hunting season does not indicate that conditions have not changed. Our study period, 2000-2016, could be considered a "short" timescale and changes during September may be less drastic than winter or summer changes. The Scenario Network for Alaska and Arctic Planning (SNAP) has modeled temperatures in Nulato, Alaska from 1960-2099 and has predicted a total change of 3.6°C during September across this longer time period (Appendix B) (SNAP 2018). McNeely and Shulski (2011) also reported minimal temperature change in the same region. Water level on the Yukon River may not have a response to changing summer temperatures or precipitation rates in the same way that lakes and smaller tributaries did, and this could explain why we found variation between years instead of change over time. Although the daily water level change on the Yukon River likely influences the water level of tributaries, it is likely that changes such as erosion or sedimentation in confluences were a more important factor than overall water level. Our analysis indicated inter-annual variation may be too high to identify a trend in leaf drop and this was likely due to site-specific parameters such as vegetative species, wind occurrence, and soil moisture, all of which were discussed previously as impacting leaf drop. Additionally, hunters do not respond to seasonal means but rather seasonal variation and these swings may have more devastating impacts that are hidden by examining changes in means.

As we hypothesized, local hunters differed from non-local hunters in regard to the impacts of environmental conditions on moose harvest. In general, non-local harvest level was more affected by environmental factors. We did not identify the mechanism that links warmer days with reduced non-local harvest but estimated that a negative relationship exists during Sept 6-20. The relationship between non-local harvest and temperature may be related to fundamental moose biology, whereas warmer temperatures reduce moose activity and opportunities for encounters with hunters (McCann et al. 2013, Lenarz et al. 2009, Dussault et al. 2004). Rural Alaska communities are known for being resilient to changes in the climate (Kofinas et al. 2010) and this resilience may explain why a measurable impact of temperature on local moose harvest did not exist. Locals may have more day-to-day opportunities to hunt and may be able to select 'better weather' days opportunistically during the season. Local hunters may be able to switch hunting locations easier than non-local hunters. It would be useful to assess the number of days people spent hunting to understand if effort changed over time or was associated with environmental parameters, but these data are likely flawed due to changes in reporting rates as well as hunter memory recall. Our ability to assess the impacts of changes in reporting rates was limited. Finally, local hunters may have increased pressure to "fill the freezer" (Fig. 3.3) and this pressure may foster enhanced hunter effort to offset challenges associated with a changing environment. With rural moose hunting concentrating on navigable waterways, it is intuitive that adequate water levels are important for hunters in Interior Alaska (Johnson et al. 2016). Our results showed a strong, positive relationship between non-local moose harvest and water level from 6-20 Sept and for local hunters from 16-20 Sept. The importance of water level was most likely related to access and not moose biology or hunter behavior. Higher water allows access into sloughs located off of major rivers and enlarges the area a hunter can search.

These results contradict concerns raised by McNeeley (2009) but not necessarily Board of Game proposals written by rural entities. McNeeley raised concerns regarding the impacts of environment on moose hunters and suggested that environmental factors decrease harvest success. However, our results suggest that local harvest success is not directly impacted by environmental factors, excluding water level from 16-20 Sept. Our results indicate that non-local hunters are more limited by poor environmental conditions than local hunters. However, it is the local, rural hunters that were hypothesized to be negatively influenced by environmental factors. This study suggests that previous work underestimated the adaptive capacity of local hunters to respond to inter-annual variation. On the other hand, BOG proposals requested shifting season dates because poor environmental conditions at the beginning of the season impacted hunting opportunity. Local hunters may be challenged by these environmental factors but it does not appear that it directly impacted their harvest success, yet. Shifting the season to allow for better weather during hunting season may increase non-local harvest success.

Our study integrated remote sensing, meteorological station, and moose harvest data to address local hunter concerns and an important wildlife management issue. Water gauge stations exist across Alaska, but the change in water level was not previously used to assess hunting issues. Boat access is an important issue across interior Alaska and the use of gauge stations may help managers and researchers in other regions to address environmental barriers.

Although novel, our study did have several limitations worth addressing. Although we were able to identify early, average, or late leaf-drop years, the spatial resolution of leaf-drop data may have limited our ability to determine relationships with moose harvest in Interior Alaska. Future research may be able to use better technology (e.g., Sentinel satellite imagery) but there were too few years of high-resolution imagery available at the time of this research. River depth was not measured for most Yukon River tributaries used by hunters within the study region. There may be differences in water levels in some secondary stream systems. River bank erosion and sedimentation may also inhibit access (Brown et al. 2018). These changes were not addressed in this study, but warrant additional exploration. We only assessed the impacts of environment on successful hunters, but we acknowledge that non-successful hunters may be an important group to evaluate. We recommend that wildlife agencies improve records on the activities of unsuccessful hunters in order to accurately gauge the impacts of environment on success and to enhance hunt satisfaction.

This research was important because it directly addressed community concerns and a growing wildlife management issue. Our research was designed to assess local concerns and was possible through a series of informal meetings, frequent progress reports, and aid by tribal councils. Although growing season was previously assessed by the Geographic Information Network of Alaska (GINA), the results were never disseminated, made available, or updated. In order to be helpful in local communities, results from studies such as this one need to be provided to the community in an understandable way. Community input was central to the design and importance of this study, and we recommend using this type of research approach in future research.

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3.8 Figures

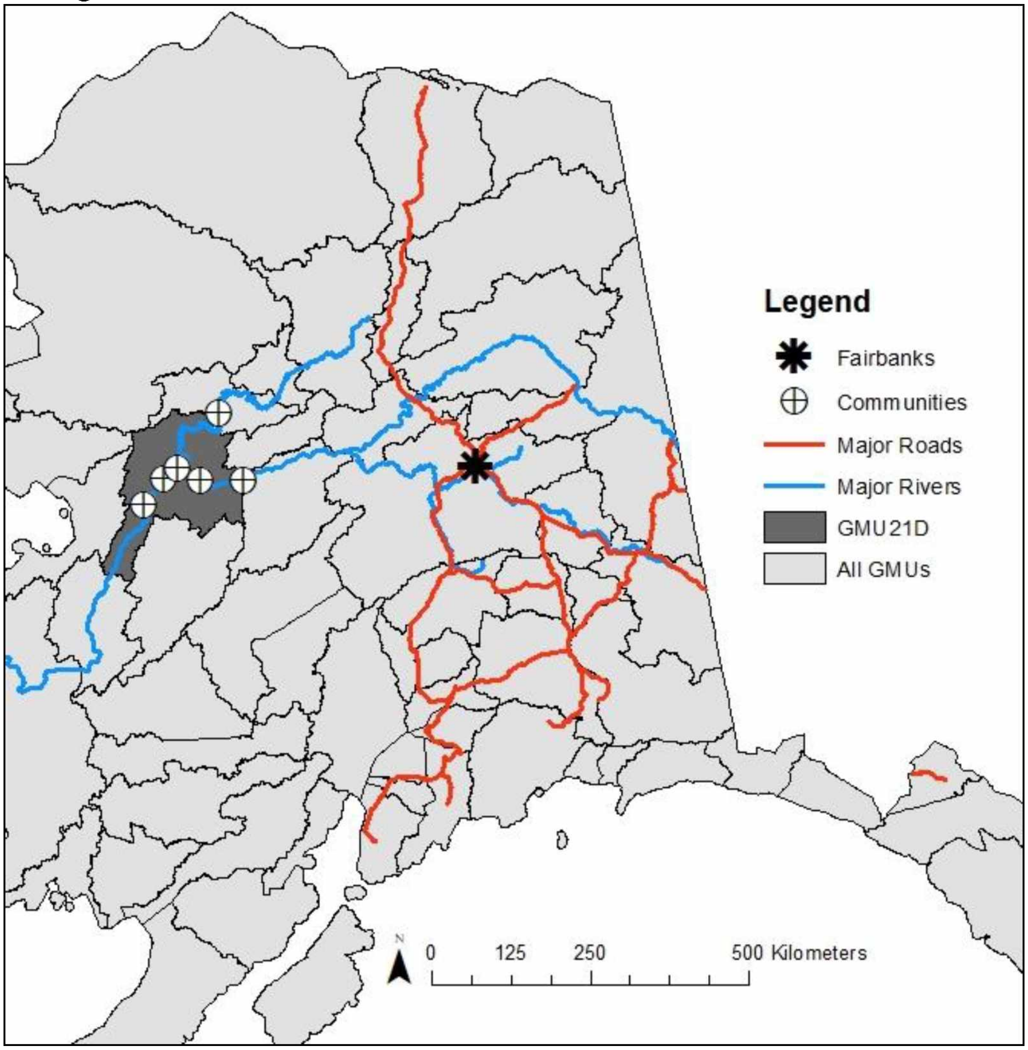


Figure 3.1. Map depicting the study area (Game Management Unit 21D) in relation to Fairbanks, Alaska.

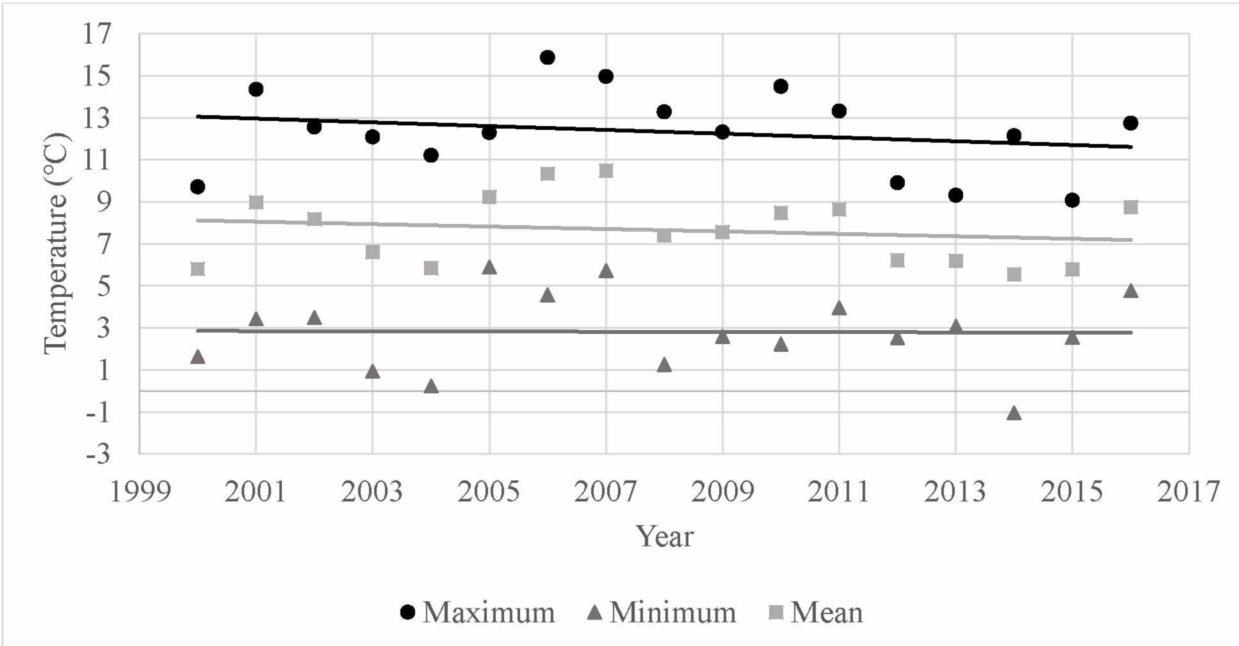


Figure 3.2. Annual maximum, minimum, and mean temperature for Galena, Alaska from 2000-2016 during peak moose harvest. Solid lines represent linear trendlines.

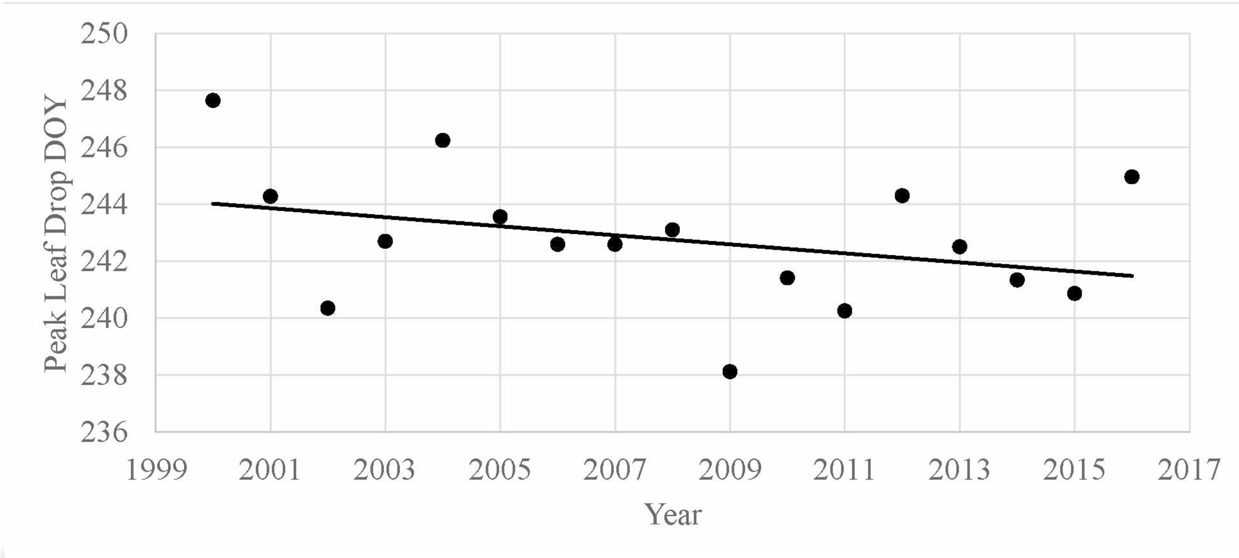

Figure 3.3. Mean day of year (DOY) of peak leaf drop from 2000-2016 across entire study area. DOY is based on Julian day and solid line represents linear trendline.

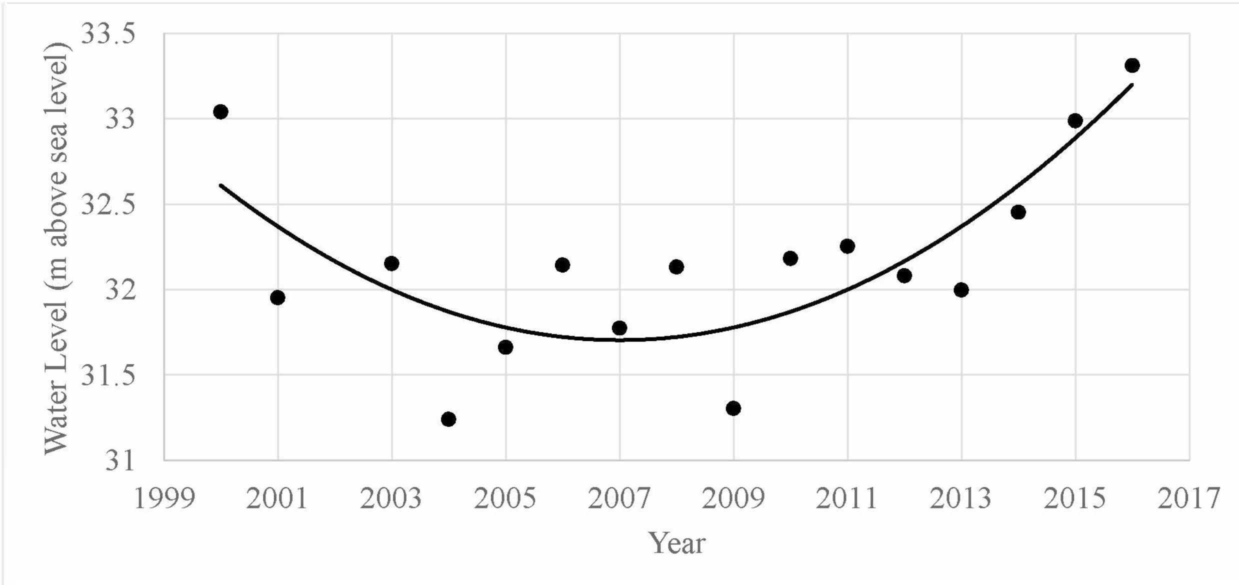

Figure 3.4. Annual water level (m above sea level) of USGS Galena gauging station from 2000-2016 (missing 2002) during peak moose harvest. Solid line represents polynomial trendline.

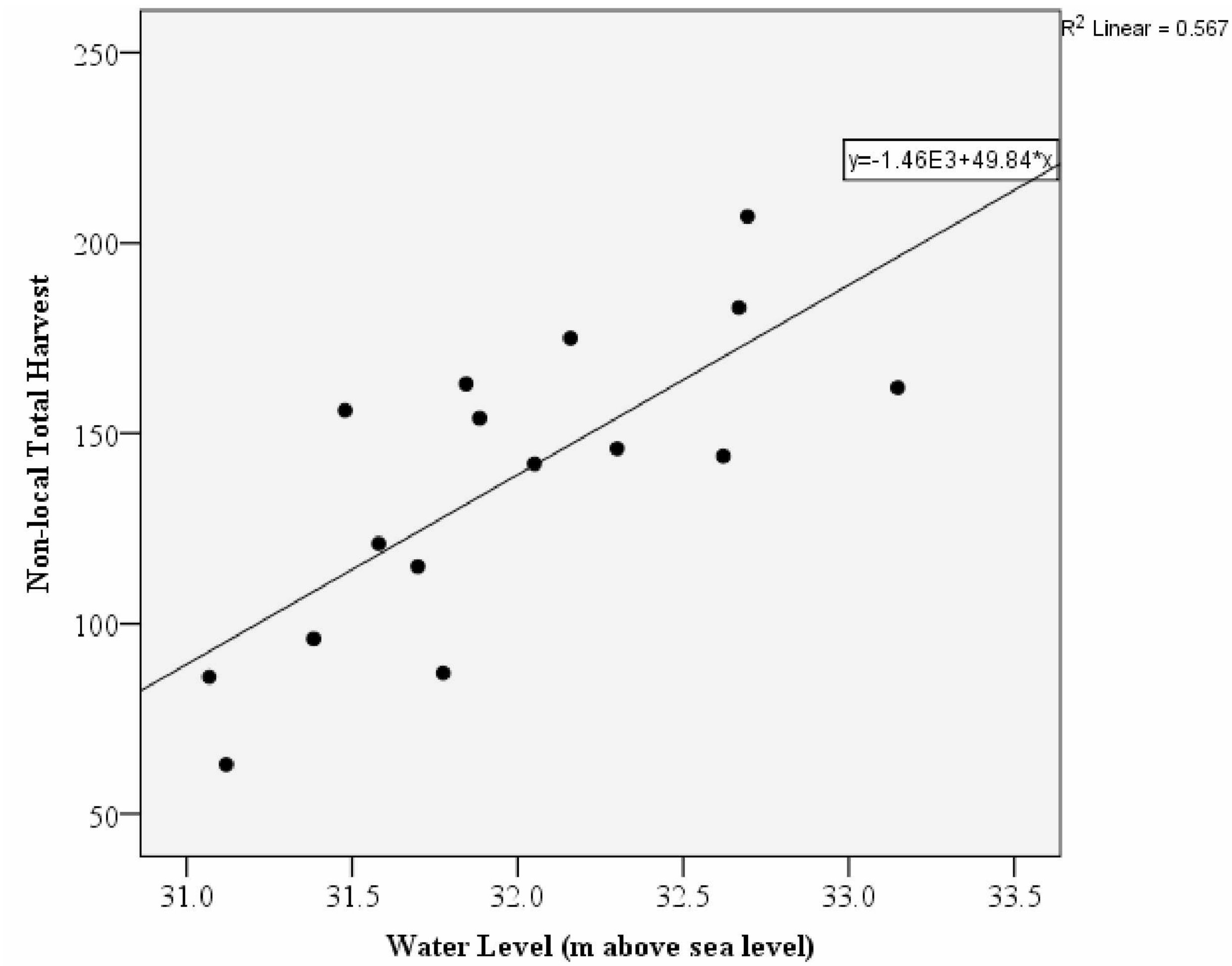


Figure 3.5. Relationship between water level and non-local total harvest from 2000-2016 in our study area. Solid line represents linear trendline.

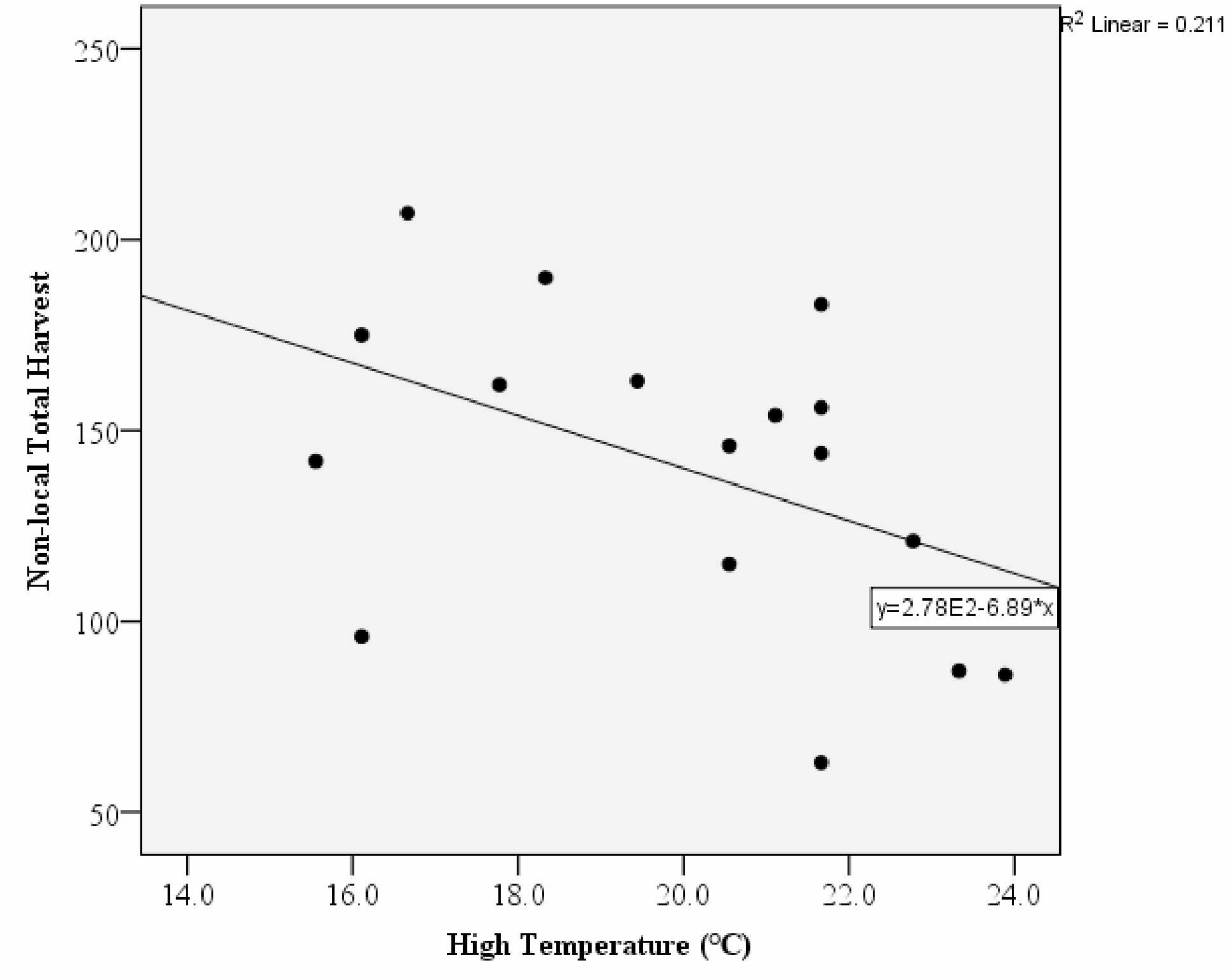


Figure 3.6. Relationship between high temperature and non-local total harvest from 2000-2016 in our study area. Solid line represents linear trendline.

3.9 Table

Table 3.1. Results from analyses. Response variables are local total harvest (L harvest) and non-local total harvest (N-L harvest). Predictor variables are high temperature (HT; °C), low temperature, (LT; °C), mean temperature (MT; °C), leaf drop date (LD), and water level height (WL; m above sea level). Significance symbolized *(p=0.10), **(p=0.05), and ***(p<0.01)

| Response Variable | Predictor | p-value | $R^2$ | Equation for Best Fit Line | Line $R^2$ |
|---|---|---|---|---|---|
| Coarse Scale (annual) | | | | | |
| L harvest | HT | 0.946 | 0.00 | - | - |
| L harvest | LT | 0.465 | 0.04 | - | - |
| L harvest | LD | 0.621 | 0.02 | - | - |
| L harvest | WL | 0.146 | 0.15 | - | - |
| N-L harvest* | HT | 0.064 | 0.21 | y = 2.78E2-6.89x | 0.21 |
| N-L harvest | LT | 0.3 | 0.07 | - | - |
| N-L harvest | LD | 0.841 | 0.00 | - | - |
| N-L harvest*** | WL | 0.001 | 0.57 | y=-1.43E3+49.84x | 0.57 |
| | | | | | |
| Fine Scale (5-day) | | | | | |
| L harvest (Sept 1-5) | MT | 0.721 | 0.00 | - | - |
| L harvest (Sept 6-10) | MT | 0.266 | 0.02 | - | - |
| L harvest (Sept 11-15) | MT | 0.656 | 0.00 | - | - |
| L harvest (Sept 16-20)* | MT | 0.094 | 0.03 | y=6.71-.17x | 0.03 |
| L harvest (Sept 21-25) | MT | 0.899 | 0.00 | - | - |
| L harvest (Sept 1-5) | WL | 0.456 | 0.01 | - | - |
| L harvest (Sept 6-10) | WL | 0.622 | 0.00 | - | - |
| L harvest (Sept 11-15) | WL | 0.165 | 0.03 | - | - |
| L harvest (Sept 16-20)** | WL | 0.003 | 0.13 | y=-61.3+2.1x | 0.13 |
| L harvest (Sept 21-25) | WL | 0.385 | 0.01 | - | - |
| N-L harvest (Sept 1-5) | MT | 0.738 | 0.00 | - | - |
| N-L harvest (Sept 6-10)** | MT | 0.003 | 0.10 | y=6.17-.41x | 0.10 |
| N-L harvest (Sept 11-15)** | MT | 0.02 | 0.06 | y=8.48-.26x | 0.06 |
| N-L harvest (Sept 16-20)*** | MT | <0.001 | 0.15 | y=13.81-0.49x | 0.15 |
| N-L harvest (Sept 21-25) | MT | 0.947 | 0.00 | - | - |
| N-L harvest (Sept 1-5) | WL | 0.568 | 0.01 | - | - |
| N-L harvest (Sept 6-10)** | WL | 0.022 | 0.08 | y=-41.06+1.41x | 0.08 |
| N-L harvest (Sept 11-15)** | WL | 0.019 | 0.09 | y=-40.48+1.45x | 0.09 |
| N-L harvest (Sept 16-20)*** | WL | 0.001 | 0.18 | y=-83.45+2.94x | 0.18 |
| N-L harvest (Sept 21-25) | WL | 0.342 | 0.01 | - | - |

3.10 Appendices

Appendix A: Board of Game proposals illustrating efforts by local entities to request changes in hunting season dates due to inferior weather conditions during current moose hunting seasons.

2016/17 BOG Proposal

**PROPOSAL 94 -5 AAC 85.045. Hunting seasons and bag limits for moose**. Modify the hunting season for moose in Unit 21D as follows:

The solution proposed is a later, fall season for RM834 to accommodate warmer fall weather as stated below:

Remainder of Unit 21D RESIDENT HUNTERS: 1 moose per regulatory year [AUG. 22—AUG. 31] **Sept. 1** [SEPT. 5] —**Sept. 30** [SEPT. 25]

The solution proposes no additional hunting days to the hunting season. Increased opportunity is provided only through a shift in the season dates.

**What is the issue you would like the board to address and why?** Weather patterns in this area have changed, producing warmer fall seasons and resulting in lack of moose movement earlier in the season, and greater potential for meat spoilage. In addition, later green vegetation presence hinders visibility for hunting. Shifting the season dates to respond to these changing weather patterns would better accommodate harvest opportunity and quality of harvest for residents in this area without adding days to the existing season.

**PROPOSED BY:** Galena Village (EG-C15-016)

2016/17 BOG Proposal

**PROPOSAL 123 -5 AAC 85.045. Hunting seasons and bag limits for moose**. Lengthen the resident hunting season for moose in Unit 20D as follows:

**Seasons and bag limits for moose in Unit 20D**

That portion of Unit 20D which is south of the north bank of the Tanana River and east of the west bank of the Johnson River, except that portion within the Robertson River drainage south of the confluence of the east and west forks, and within one mile of the west fork. Alaska Residents -One bull Sept. 1—**Sept. 20** [SEPT. 15]

With the vast amount of moose browse just across the Tanana River created by the 463,994 acre Billy Creek burn in 2004, good wolf trapping reports from the north side of the Tanana and with the Macomb Plateau Controlled Use Area to the south, overharvest should not be an issue.

**What is the issue you would like the board to address and why?** Local residents report that moose movement along the Tanana River Valley in eastern Unit 20D during the first part of September (the first part of the existing hunting season) is very slow, especially during a warm fall, and that rutting behavior is minimal until the last few days of the current hunting season. Extending the hunting season until September 20 would provide hunters with a better opportunity to harvest a bull moose. A bit more hunting opportunity in this area would be appreciated.

**PROPOSED BY:** Tom Geyer (EG-F16-025)
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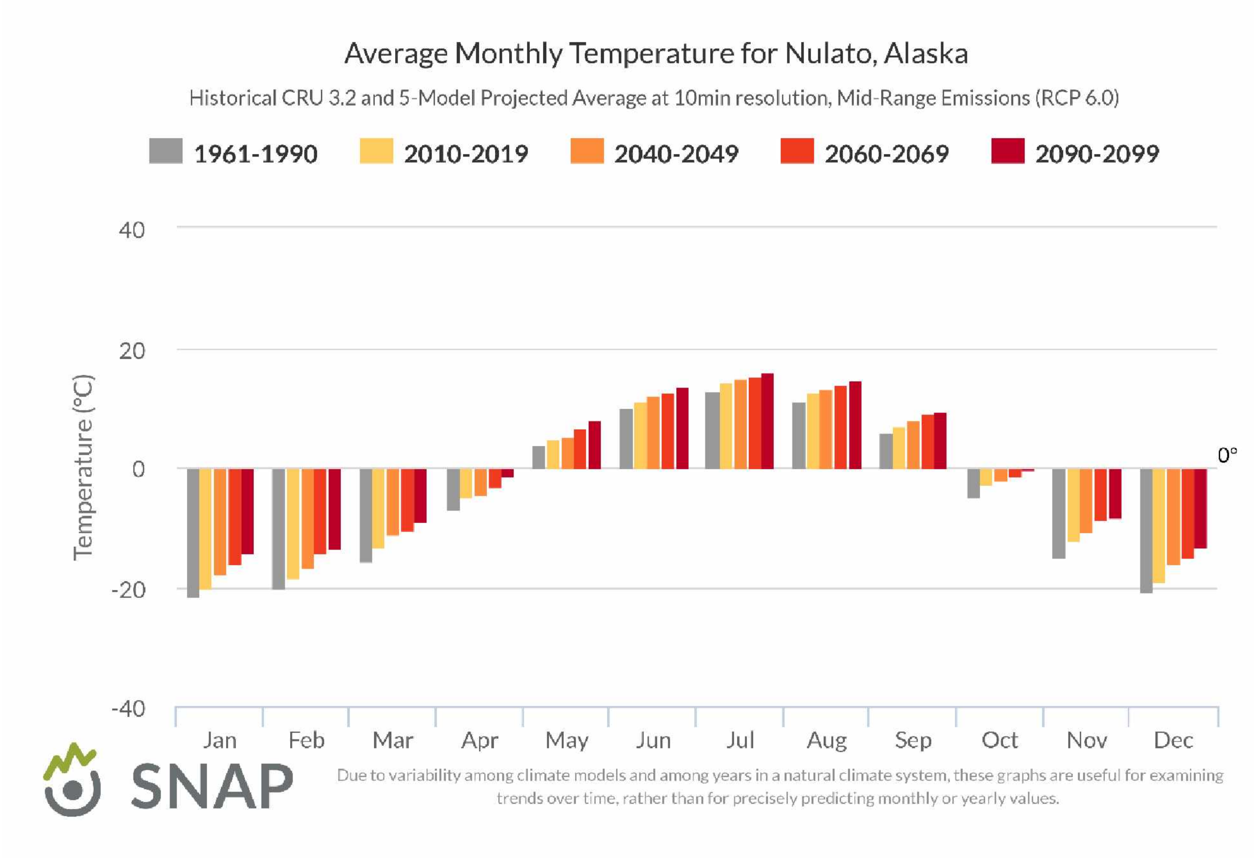
Appendix B: Average monthly temperature projection for Nulato, Alaska. Created by Scenario Network for Alaska and Arctic Planning using Historical CRU 3.2 and 5-Model projected average at 10min resolution, mid-range emissions (RCP 6.0) (SNAP 2018).



## Chapter 4: Conclusion

My research demonstrated a novel analysis of hunter competition and the effects of environmental factors on hunter success. As a case study, I addressed issues important to rural communities and wildlife managers by focusing on moose harvest in Interior Alaska. Objectives were outlined by Nulato Tribal Council and Koyukuk Traditional Council and I used publicly available data, novel remote sensing techniques, and moose harvest records to address the questions at hand. Some moose harvest data are publicly available but I received location of kill through a data agreement with ADFG. Specifically, I performed an assessment of moose harvest patters in urban and rural regions, and conducted a more detailed study in the rural region of differences in moose harvest patterns between local and non-local hunters. I identified areas and time periods with the greatest hunter competition, and identified relationships between environmental factors and hunter harvest. Both of these findings are highly likely to advance moose management and productive conversations between moose managers and local stakeholders.

The association between local moose harvest and environmental conditions did not match our partners' expectations. Temperature and leaf drop did not have a measurable impact on harvest success, and water level was only significantly associated with harvest during a portion of the month (16-20 Sept), which coincidentally was also peak harvest. These results contradict the conclusion of McNeeley's (2011) work on the "Anatomy of a closing window" which suggested that harvest success is confined by strict regulations and limited time during hunting season with ideal weather conditions. I did not test the implications of "strict regulations" in the area but Chapter 2, Figure 1 may demonstrate that regulations are relatively liberal compared to other locations. Current regulations consider hunter needs, hunter safety, and biological risks to the moose population. As an example, extending the current season into the rut may cause delayed impregnation subsequently extending spring calving, therefore decreasing calf survival the following winter. My research demonstrated that the number of moose harvested by locals was not significantly associated with environmental conditions as McNeeley (2011) had hypothesized. However, my research did not necessarily contradict the Board of Game proposals submitted by tribal councils requesting lengthening the hunting season due to decreased hunt opportunities caused by environmental conditions. Local hunters could be increasingly challenged by environmental factors, but these challenges have not yet influenced harvest success. Future research should consider non-successful hunters and include a metric for effort. Shifting the season to include better weather conditions could possibly increase the number of moose harvested by non-local hunters. This result would potentially increase competition between local and non-local hunters.

Moose harvest systems are incredibly complex, however. The belief that climate-wildlife-hunter interactions will follow a smooth trendline is over-simplified and potentially implausible. I concluded that the average local hunter's success is not impacted by warm temperatures, but this does not account for how hunters may have adapted to and overcome challenges associated with varying temperatures. Environmental conditions may be increasing challenges for local hunters without impacting actual harvest success. I addressed the concerns outlined by communities with the best available tools. Although our analyses were novel and more quantitative than any previously completed (to our knowledge) it is possible that we failed to account for important factors. These other factors and challenges may increase hunter stress and decrease hunter satisfaction but the data available and methods used in this research did not allow us to examine those factors.

I implemented a novel approach with the best available data, but improvements to understanding this system will continue to improve as data improves. As social and ecological factors continue to change through time and as technology and the resolution of these data continue to advance, I speculate that our research questions will need to be re-visited. This research has not "closed the book" on the matter but rather has shed light on a handful of key relationships. Athabascan communities are known to be good at adapting to climatic changes (Kofinas et al. 2010) and will continue to do so. Continuing to explore these questions, and maintaining open two-way dialogue with stakeholders, may help sooth stress associated with moose hunting challenges. In a dream world with unlimited funding, IRB approval, and public participation, I believe that interviews and surveys would help address the hunter competition question in a more holistic manner by better assessing hunter expectations and effort. Additionally, simultaneously tracking individual local hunters, non-local hunters, and moose would be beneficial by providing finer spatial resolution of overlap.

The process and the outcome of this project have helped me create several management recommendations. First, management agencies should collect better information from hunters, especially non-successful hunters on metrics such as number of days hunted, location, hunt patterns, success rate of group, hunt satisfaction, and factors that limited success. It is difficult to measure the impacts of parameters on harvest without having an adequate metric for effort for those that do not harvest. Also, many people hunt in groups and may only attempt to harvest fewer moose than the number of hunters in the group because of the size of the animal. Therefore, information is lacking for the hunter that does not report the hunt as successful, even though he or she considers it to be when someone in the group harvests a moose. Hunters could benefit from providing more information because it would allow managers to more precisely estimate how to promulgate regulations. Without precise information managers are forced to manage with caution and err on the side of conservative harvest. Second, I recommend enhancing and maintaining open communication on these topics with stakeholders. Communication can be through newsletters, small meetings with councils or communities, or information flyers at the checkpoint station. Stakeholders are more likely to comply with management if they are part of a transparent process (Riley et al. 2018). I will communicate the results of this research with our community partners and wildlife managers to facilitate dialogue. Finally, as stated previously I recommend continuing to monitor environmental and competition parameters, and seek higher resolution data to assess associations.

For researchers interested in working collaboratively with rural communities, I have the following recommendations. Community collaborative research can be a scientifically and socially rewarding process and was my favorite aspect of the project. There is no standardized way to do a collaborative project that will work with every stakeholder group, and tips are likely to change by region, by community, by researcher, by season, or by day. I argue that outside researchers should exhibit 3 main characteristics: patience, humility, and active listening. “Getting the ball rolling” can be a slow process. Nulato Tribal Council formed their research questions over the course of 6 months whereas Koyukuk Traditional Council formed their research objectives in 18 months. This required patience and a lot of in-person interaction to build trust. Local leaders within communities tend to be inherently busy as they wear “many hats.” I noticed that it is common for councils to be simultaneously dealing with planning memorial potlaches, participating in hunting/fishing seasons, supporting school sporting events, attending cultural camps, implementing suicide or drug prevention programs, hiring for community construction projects, and more. Humility is important because researchers need to understand that they may not be a priority in rural communities, even if research is collaborative.

Recognizing that you may not be remembered by people if you do not have frequent enough personal contact is important. This should be more than showing up for an afternoon, giving a report, and flying back home. If a researcher has time to show up for a few days to sit around and hear stories, it will enhance the experience of all groups and will help strengthen trust. In conclusion, I suggest showing up, shutting up, drinking some coffee, and listening as people share their stories.

References

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